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RESPONSE OF CERTAIN VARIETIES OF VITIS VINIFERA TO GIBBERELLIN[1]

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INTRODUCTION

SINCE GIBBERELLIN has been shown to have a marked effect on stem elongation, flowering, and set of fruit in many plants (Brian and Henning, 1955; Marth *et al.,* 1956; Lindstrom *et al.,* 1957; Stowe and Yamaki, 1957; Weaver, 1957; Wittwer and Bukovac, 1957), experiments were conducted in 1957 to determine the effects of this regulator on two seedless and five seeded varieties of grapes.[3] Grapes, especially seedless varieties, have previously been shown to be very responsive to other plant regulators (Weaver and Williams, 1950; Weaver, 1956). One objective of the work presented here was to study the response of vines to various concentrations of gibberellin applied at different stages of development. The effect in relation to set of fruit, berry size, and rate of flowering and ripening was noted. Since one of the most striking responses of plants to gibberellin is a lengthening of shoots and stems, special emphasis was given to its effects on length and size of peduncle, rachis with its laterals, and pedicels. Attention was also given to the response of the vegetative portions of the vine. The effect of gibberellin on length of shoots and internodes, rate of elongation, and other responses was observed. An objective of one experiment was to determine how readily gibberellin translocates in the grape shoot.

MATERIALS AND METHODS

Mature vines of Black Corinth, Thompson Seedless, Zinfandel, Tokay, Ribier, Red Malaga, and Muscat of Alexandria in the irrigated vineyard at the University of California at Davis were used. Black Corinth, a raisin grape, and Thompson Seedless, treated as a table grape in these experiments, were usually pruned to four canes (Winkler, 1931). Zinfandel, a wine grape, and Muscat of Alexandria, a raisin or table grape, were head-trained and spur-pruned. Tokay, Ribier, and Red Malaga, all table grapes, were cordon-trained and spur-pruned.

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In all spray experiments, both clusters and foliage were heavily sprayed to runoff. One-quart hand sprayers or De Vilbiss No. 15 atomizer sprayers were used for spraying individual shoots, and 3-gallon sprayers for entire vines. It is emphasized that there were no repeated applications in any experiment; a given vine or cluster was treated only once.

The water-soluble potassium salt of gibberellic acid, supplied by Merck and Company, which was assumed to contain 80 per cent of active ingredient, was used. For convenience, this compound is referred to throughout this paper as "gibberellin." It is furthermore possible that other "gibberellin-like" substances were present in the mixture. All concentrations are expressed in parts per million on an acid-equivalent basis. Dreft was added to the aqueous solutions for a wetting agent.

Length of cluster, unless otherwise stated, was measured from base of peduncle to apex.

At harvest or sampling time the berries were removed from the clusters and thoroughly mixed, and the weight of 100 or 200 was obtained in duplicate to determine berry size. The remaining berries were crushed, and the percentage of total soluble solids in the juice was determined with a Balling hydrometer and expressed as degrees Balling. Total acidity was determined by diluting 10 ml of the juice to 50 ml with distilled water and titrating with 0.133 *N* NaOH, using phenolphthalein as an indicator. The results are expressed as grams of tartaric acid per 100 ml of juice, which is approximately the percentage of acid.

EXPERIMENTATION AND RESULTS

Black Corinth

Girdling has long been practised to induce set in Black Corinth grapes. In recent years, however, girdling in Black Corinth has largely been replaced by spraying with the plant regulator 4-chlorophenoxyacetic acid, both in California (Weaver, 1956) and Australia (Coombe, 1953). This chemical has also been used on a small scale for this purpose in Greece (Weaver *et al.*, 1957).

Dipping Experiments. Clusters of Black Corinth were dipped in gibberellin, and their responses at full bloom and three days after all calyptras had fallen were observed. The first treatment was made at 10:00 A.M. on May 22, 1957, at full bloom. (Full bloom in this paper is considered to be that time when about 70 per cent of the calyptras have fallen.) Clusters were dipped in solutions containing 0, 1, 5, 20, 100, or 500 ppm of gibberellin, ten replicate clusters per treatment. On the same day 0.37 inch of rain fell between 3:00 P.M. and 8:00 P.M.

On June 7 a high percentage of berries about 2 mm in diameter was set on the control clusters. In 1957, as compared with certain other years, there was an excellent set in untreated, ungirdled vines. Treatment with gibberellin at 1 ppm resulted in somewhat straggly clusters, as many berries failed to set or enlarge. Larger berries were 4–5 mm in diameter. Vines treated with concentrations of 5, 20, and 100 ppm showed excellent sets of berries, 5–6 mm in diameter. Application of the compound at 500 ppm resulted in very large,

elongated berries. On July 3 coloring was beginning on clusters treated with concentrations of 100 or 500 ppm. Fruit was harvested on July 30. Since the results were very similar to those of the second treatment, the harvest data are not presented.

A second series of clusters was similarly dipped on May 31, about three days after all the calyptras had fallen. Fruit was harvested on July 30. At concentrations of 100 or 500 ppm, the length of cluster was apparently only slightly increased (table 1, fig. 1). Although no supporting data were collected, the laterals of the rachis and the pedicels of some dipped clusters appeared thicker and longer than those of clusters from adjacent girdled vines (fig. 2). This would account for the fact that treated clusters were no more compact, irrespective of their large berries, than those from adjacent girdled vines. The weight per cluster and average weight per berry increased with higher concentrations (table 1, fig. 3). Clusters dipped in solutions containing 500 ppm of gibberellin were about two and a half times heavier than those hanging on adjacent girdled vines. The degree Balling reading was lower in clusters treated with the compound at 20, 100, and 500 ppm than in those treated at the two lower concentrations—probably because of the greater weight of the former.

TABLE 1

DATA AT HARVEST (JULY 30) FOR UNGIRDLED BLACK CORINTH GRAPES DIPPED IN SOLUTIONS OF GIBBERELLIN ON MAY 31

Figures are averages of ten replicates

Concentration of gibberellin (ppm)	Length of cluster (cm)	Length peduncle to basal branch (cm)	Weight per cluster (gm)	Weight per berry (gm)	Degree Balling reading	Total acid, per cent tartaric
0	23.8	2.01	91.6	0.26	23.4	1.75
1	24.0	....	206.5	0.47	23.6	1.50
5	23.9	....	258.0	0.58	23.9	1.29
20	24.9	....	366.6	0.78	21.3	1.34
100	26.7	....	391.3	0.99	23.0	1.26
500	27.5	2.16	500.7	1.31	22.6	1.30

Ten oval berries selected at random from the clusters treated at 500 ppm averaged 13.8 mm in length and 10.1 mm in width. The average diameter of round berries from adjacent girdled vines was 6.5 mm (fig. 3).

Spraying Experiment. In this experiment entire vines of Black Corinth were sprayed with gibberellin. On May 31, about three days after calyptras had fallen, ungirdled vines were sprayed with concentrations of 5 or 20 ppm, four vines per treatment. Another set of vines was neither girdled nor sprayed, and a fourth set was girdled but not sprayed. On June 7 berries on ungirdled, unsprayed vines were about 2 mm in diameter, while those on girdled and on sprayed vines had a diameter of 4–5 mm. On July 17 about 40 per cent of the total surface of fruit from girdled vines was colored; on the ungirdled vines sprayed at 5 and 20 ppm, the amount of coloration was 15–20 per cent. Retarded coloration of the sprayed fruit was no doubt correlated with a much heavier crop (table 2).

On August 5 all clusters from two canes, or half the crop of each vine, were harvested. The remaining half was harvested on August 23 (table 2). An excellent set of berries, much larger than those of the girdled vines, was produced by gibberellin at 5 ppm. The largest berries and the largest clusters were produced by a concentration of 20 ppm. Pedicels of these sprayed clusters were one and a half to two times as long and as thick as those of clusters from girdled vines. This probably accounts for the fact that sprayed clusters were not compact regardless of their large berries (fig. 4). Fruit from sprayed vines was lower in degree Balling than girdled fruit, probably because of the larger crop on sprayed vines. The percentage of acid was also lower in the fruit from sprayed vines (table 2).

TABLE 2

DATA FOR BLACK CORINTH AT HARVESTS (AUGUST 5 AND AUGUST 23) AFTER BEING SPRAYED WITH GIBBERELLIN ON MAY 31

Figures are averages of four replicates

Treatment, concentration of gibberellin (ppm)	Weight per cluster (gm)	Weight per berry (gm)	Degree Balling reading	Total acid, per cent tartaric
Harvested August 5				
0 (not girdled)	....	0.13	17.9	1.38
5 (not girdled)	....	0.49	13.7	1.17
20 (not girdled)	....	0.67	15.2	1.12
0 (girdled)	....	0.31	16.3	1.28
Harvested August 23				
0 (not girdled)	59.8	0.14	27.7	0.85
5 (not girdled)	122.0	0.47	23.2	0.85
20 (not girdled)	215.9	0.65	23.5	0.89
0 (girdled)	131.7	0.35	24.1	1.02

Thompson Seedless

In California, Thompson Seedless vines are generally girdled to produce large berries for table use. The plant regulator 4-chlorophenoxyacetic acid has also been used on a limited scale for the same purpose (Weaver, 1956). The following experiments were designed to study the response of vines at various stages of development to different concentrations of gibberellin applied to individual shoots or entire vines. The objective of one experiment was to determine whether gibberellin moves readily from one part of a shoot to another.

Shoot Applications. Shoots were sprayed with gibberellin at 0, 1, 10, 100, or 1,000 ppm, ten shoots per treatment. The first series was treated on April 23, when shoot length averaged 7 inches and the larger clusters averaged about 2 inches from the basal branch to the apex. Five leaves were usually expanding, and each shoot bore one or two clusters. The second series was sprayed on April 29, when shoot length averaged 8–9 inches and the clusters

were 2½–3 inches long. A final series was treated on May 29 at full bloom.

Within two or three days after the treatment on April 23 foliage and stems on shoots sprayed with gibberellin at 10 ppm were slightly yellowish, the intensity of the color increasing with higher concentrations. One week later all shoots except those sprayed with 1,000 ppm were becoming a more normal green. Similar yellowing of shoots as a result of gibberellin applications was observed with all varieties tested and was usually more noticeable on younger shoots. On April 29, six days after treatment, clusters sprayed at 100 or 1,000 ppm were larger than the controls. On May 9 control clusters were 4–5 inches long, but those treated at 1,000 ppm were about 12 inches long. By May 17 flowering was beginning on shoots sprayed with a concentration of 1,000 ppm. On May 29 the percentages of calyptras that had fallen from clusters sprayed with concentrations of 0, 1, 10, 100, or 1,000 ppm were about 60, 60, 60, 75, and 100 per cent, respectively (fig. 5). This indicates that gibberellin hastens flowering. Shoots sprayed on April 23 with concentrations of 0, 1, 10, 100, or 1,000 ppm were 32, 34, 36, 48, and 65 inches long, respectively, on June 13. Further measurements were not made, as too many shoots had been broken by the wind and cultivators.

Grapes were harvested on August 26 (table 3). Although clusters were longer on vines sprayed at 100 or 1,000 ppm on April 23, they contained many shot berries[4] of varying sizes (fig. 6). Length of peduncle and lateral of rachis was increased by a concentration of 1,000 ppm. The average weight per cluster was lower in sprayed shoots, probably owing to the presence of many shot berries. Gibberellin increased degree Balling reading but had little effect on percentage of acid.

The results of the second treatment, applied on April 29, were generally similar to those of the first (table 3). This was to be expected, as there was only a six-day interval between treatments.

One month after the third treatment, applied on May 29, berries on vines that had been sprayed with the compound at 1 ppm were slightly elongated. Progressively larger clusters with more elongated berries resulted from higher concentrations. For example, berries treated on May 29 with gibberellin at 1,000 ppm were about 20 mm long and 13 mm wide. Data at harvest (table 3) for the third treatment indicate that there was little or no elongation of parts of the cluster framework. Weight of cluster, weight of berry, and extent of berry elongation usually increased with higher concentrations (table 3, figs. 7 and 8). Gibberellin at 100 and 1,000 ppm depressed the degree Balling reading, probably because the clusters in these treatments were much heavier. Berries treated with concentrations of 100 and 1,000 ppm broke off at the base of the pedicel more readily than those of other treatments.

Spraying of Entire Vines. The purpose of one vine-spraying experiment was to determine the response of Thompson Seedless to gibberellin after the shatter of impotent flowers following bloom. One objective was to ascertain whether effects similar to girdling could be obtained. On June 10, after berry shatter, vines were cluster-thinned to five clusters per cane, and the remaining clusters were berry-thinned by removing the apical half (Winkler,

[4] Shot berries are small, round, seedless berries.

1931). The following day vines were sprayed with concentrations of 5, 20, or 50 ppm, four vines per treatment. One set of vines was neither girdled nor sprayed, and another set was trunk-girdled but not sprayed.

Fruit was harvested on August 26. Clusters and berries sprayed with gibberellin at 5 ppm were larger than those unsprayed and ungirdled, but

TABLE 3

DATA AT HARVEST (AUGUST 26) FOR FRUIT FROM THOMPSON SEEDLESS SHOOTS SPRAYED WITH GIBBERELLIN

Averages of 10 replicate clusters

Treatment, concentration of gibberellin (ppm)	Length of cluster (cm)	Length of peduncle (cm)	Length 2d lateral from basal end (cm)	Weight per cluster (gm)	Wieght per berry (gm)	Degree Balling reading	Total acid, per cent tartaric
			Sprayed April 23				
0	26.4	3.7	10.9	644	1.15	19.5	0.82
1	22.7	3.4	10.8	540	1.11	20.9	0.80
10	22.6	3.4	9.2	407	1.12	21.7	0.79
100	30.1	3.5	11.0	574	0.97	20.1	0.77
1,000	32.6	5.9	11.9	460	1.01	21.8	0.79
			Sprayed April 29				
0	24.2	3.4	....	559	....	19.6	0.81
1	21.9	3.2	....	475	....	18.5	0.81
10	26.8	3.8	....	583	....	20.7	0.82
100	35.1	4.4	....	641	....	19.6	0.85
1,000	40.2	5.8	....	506	....	21.1	0.73
			Sprayed May 29				
0	27.7	4.4	10.1	509	1.14	21.1	0.84
1	26.8	3.0	10.5	437	1.30	21.8	0.83
10	29.5	3.6	11.4	740	1.55	21.6	0.87
100	30.0	4.5	13.6	1227	1.82	18.1	0.91
1,000	29.6	3.7	12.1	1581	2.83	17.1	0.87
(1)*	2.4	0.4	....	113	0.67	0.8‡	....
(2)†	1.7	N.S.	....	92	0.24	1.7	....

* L. S. D. at 5 per cent for concentrations on a given date of spraying.
† L. S. D. at 5 per cent for spraying dates at a given concentration.
‡ Degree Balling readings of fruit sprayed on April 29 are not included in statistical analyses.

smaller than those that were girdled but not sprayed (table 4, figs. 9 and 10). Very large clusters and berries resulted from concentrations of 20 or 50 ppm. Although gibberellin caused thickened pedicels (fig. 11), berries from vines sprayed at 20 or 50 ppm easily broke off from the pedicels. The percentage of total soluble solids was lowest and the percentage of acid highest in fruit sprayed with the 50-ppm concentration.

In another vine-spraying experiment, vines were cluster-thinned to five clusters per cane early in May, but in this case they were not subsequently berry-thinned. Vines were sprayed at one of four stages of development with

gibberellin at 0, 0.1, 1, 5, or 25 ppm, four vines per treatment. At the first application, on May 3, shoots ranged from 6 to 16 inches in length, and clusters were usually 2–3 inches long. A second series was treated on May 29 at full bloom, when the clusters were about 7 inches long. The shoot tips were not sprayed in this or subsequent treatments of Thompson Seedless to avoid drift of spray onto adjacent vines. When the third series of vines was sprayed on June 14, about 10 days after the shatter of impotent flowers following bloom, larger berries were about 5 mm in diameter. The final series was sprayed on July 20, when most berries were 10–11 mm in width and total soluble solids amounted to about 15 per cent.

TABLE 4

DATA AT HARVEST (AUGUST 26) FOR THOMPSON SEEDLESS GRAPES FROM VINES SPRAYED AFTER BERRY SHATTER ON JUNE 11

Figures are averages of four replicate vines

Treatment, concentration of gibberellin (ppm)	Weight per cluster (gm)	Weight per berry (gm)	Degree Balling reading	Total acid, per cent tartaric
0 (not girdled)	299	1.59	22.4	0.79
5 (not girdled)	431	1.91	23.2	0.73
20 (not girdled)	662	2.71	18.9	0.83
50 (not girdled)	975	3.15	17.6	0.94
0 (girdled)	499	2.26	23.0	0.74
L. S. D. at 5 per cent	200	0.13	0.7	0.06

Fruit was harvested on August 26 (table 5). Gibberellin applied on May 3 had little or no effect on berry size, but when applied at full bloom (May 29) at a concentration of 25 ppm, significantly larger berries resulted. Applied after berry shatter (June 14), gibberellin in the range from 5 to 25 ppm produced larger berries (table 5). Berries sprayed on June 14 with a concentration of 25 ppm were almost twice as heavy as untreated ones. There is an indication that gibberellin at 5 or 25 ppm, applied on July 29, also increased berry size slightly. Although there were no significant differences in the degree Balling readings, there was an indication that the reading in fruit sprayed on May 29 was somewhat higher, especially with the 1- and 5-ppm levels. The spraying on June 14 possibly increased degree Balling when applied at 0.1 ppm, but at 5 and 25 ppm the degree Balling was depressed, partly at least because of the heavier crop. No definite trends in degree Balling reading or percentage of acid were observed between the first (May 3) and final (July 29) treatments.

Translocation of Gibberellin within Shoots. An experiment was designed to determine whether increased elongation of shoots occurs when gibberellin is applied only to clusters or to clusters and basal leaves of shoots. Such an effect would indicate that the compound is readily absorbed by basal shoot parts and translocated to the apical parts.

Shoots bearing one or two clusters were treated on May 1, ten shoots per treatment, when they were 10–12 inches long. Approximately one third of of the total length of the shoot (4–5 inches) was apical to the upper cluster.

In one treatment clusters were dipped in gibberellin at 1,000 ppm; care was taken to keep the solution from dripping onto other parts of the shoots. In a second treatment clusters were dipped, and leaves opposite or basipetal to

TABLE 5

RESPONSE OF THOMPSON SEEDLESS GRAPES TO GIBBERELLIN APPLIED ON VARIOUS DATES. HARVESTED AUGUST 26, 1957

Figures are averages of four vines

Concentration of gibberellin (ppm)	Average weight per berry (gm)	Degree Balling reading	Total acid, per cent tartaric
Sprayed May 3			
0	1.18	21.7	0.67
0.1	1.28	20.7	0.67
1	1.27	22.0	0.63
5	1.18	20.9	0.66
25	1.21	21.7	0.66
Sprayed May 29			
0	1.33	21.7	0.76
0.1	1.35	22.8	0.77
1	1.40	23.2	0.86
5	1.48	23.4	0.86
25	1.75	22.1	0.98
Sprayed June 14			
0	1.22	21.9	0.75
0.1	1.23	22.6	0.78
1	1.45	22.0	0.72
5	1.73	20.1	0.77
25	2.29	18.3	0.83
Sprayed July 29			
0	1.25	21.4	0.73
0.1	1.24	22.4	0.71
1	1.20	20.9	0.68
5	1.43	21.3	0.74
25	1.34	21.2	0.71
L. S. D. at 5 per cent for concentrations on a given date of spraying	0.29	N.S.	....
L. S. D. at 5 per cent for different spraying dates at a given concentration	0.11	0.8	....

the clusters were sprayed with an atomizer. In a third treatment the whole shoot was sprayed. Untreated controls constituted a fourth group. Shoot length was measured at various intervals.

The results show that shoots with lower leaves treated elongated more rapidly than untreated shoots. For example, on June 14 average shoot lengths were as follows: untreated control, 39.5 inches; clusters only treated,

38.0 inches; clusters and basal leaves treated, 44.5 inches; whole shoot treated, 56.0 inches. These results indicate translocation of the compound from the basal leaves to the apical parts of the shoot. However, apparently no gibberellin moved from the cluster into the shoot.

Zinfandel

Zinfandel clusters are so compact that during berry enlargement some berries are actually pushed off the cluster by others. This often results in much rotting. One objective of the experiments on Zinfandel was to determine whether cluster parts could be lengthened by gibberellin applications so that the cluster would be less compact.

TABLE 6

EFFECT OF GIBBERELLIN SPRAYED ON ZINFANDEL SHOOTS ON APRIL 7 ON PEDICEL LENGTH AND FLOWERING

Concentration of gibberellin (ppm)	Range in pedicel length (mm)			Percentage of calyptras fallen		
	May 9	May 17	May 21	May 9	May 17	May 21
0	1–2	....	4	0	2	..
1	4	....	5–6	0	10	..
10	4–5	....	6–7	0	8	..
100	8–9	....	8	1	40	95
1,000	14.0	....	14–17	10	80	100

Shoot applications. Zinfandel shoots usually bearing two clusters were sprayed with gibberellin at concentrations of 0, 1, 10, 100, or 1,000 ppm on one of each of three dates, ten vines per treatment. At the first treatment, on April 7, shoots were 2–3 inches long with four leaves expanding, and the clusters were ¼–½ inch long. A second series was sprayed on April 27 when shoots ranged from 8 to 12 inches long, and clusters were 1½–2½ inches long, excluding the peduncle. The final series of vines was treated on May 27, two or three days after full bloom.

Results of First Treatment (April 7). Within eight days after treatment shoots sprayed at concentrations of 100 or 1,000 ppm were noticeably longer than controls or other treatments (fig. 12). Shoots elongated in proportion to the concentration of gibberellin used (fig. 13). This held true in other varieties discussed although all the measurements are not included in this report.

On April 22 control clusters were 1–2 inches long, while those sprayed at 1,000 ppm were about 5 inches long. Many of the latter shoots, however, had a slight reddish cast, and there was some leaf browning.

On May 9, 32 days after treatment, shoots sprayed with regulator at 1 ppm were longer and had larger clusters and longer pedicels than the controls (table 6). Cluster parts sprayed at 10 ppm were already much longer than those of the controls. In the 100 and 1,000 ppm treatments flowering was beginning, and by May 21 was almost completed (table 6, figs. 14 and 15). Clusters sprayed at 1,000 ppm were twisted and bent on May 9, and about

three weeks later they had failed to set fruit and were drying. On May 28 longitudinal splitting or cracking was evident on shoots of this treatment, and about two weeks later these shoots were much redder than the controls. Longitudinal splitting had become more striking. After the middle of June the stimulation of shoot growth resulting from gibberellin markedly decreased (fig. 13).

TABLE 7

LENGTH OF INTERNODES ON ZINFANDEL GRAPE SHOOTS MEASURED AT HARVEST (SEPTEMBER 23) AFTER SPRAYING WITH GIBBERELLIN AT SEVERAL CONCENTRATIONS ON APRIL 7, APRIL 27, OR MAY 27

Figures are averages of ten replicates

Treatment, concentration of gibberellin (ppm)	Length of internode (cm)						
	1st	2d	3d	4th	8th	12th	16th
Sprayed April 7							
0	3.0	4.1	5.6	7.0	8.2	7.5	7.8
1	3.0	4.7	6.3	7.7	10.2	9.4	9.3
10	3.6	5.4	7.3	9.5	11.4	11.2	9.0
100	4.7	6.4	9.2	10.9	13.9	11.4	9.6
1,000	5.8	7.5	11.4	13.6	16.7	15.5	10.1
Sprayed April 27							
0	3.3	4.8	6.1	8.1	8.9	7.9	6.8
1	3.9	5.2	7.2	8.7	12.1	9.7	8.0
10	4.3	4.8	6.5	9.2	11.5	9.2	9.4
100	3.5	5.1	5.9	9.1	13.4	11.5	9.1
1,000	3.5	5.0	6.2	9.9	15.8	16.2	12.6
Sprayed May 27							
0	3.4	4.7	5.7	8.2	8.5	7.6	5.8
1	3.5	4.7	5.4	7.0	9.1	7.9	7.9
10	3.6	4.5	5.5	6.8	8.1	7.6	9.0
100	3.4	4.7	5.6	7.1	8.1	7.1	8.2
1,000	3.5	4.7	6.0	7.7	9.0	7.3	11.4

Canes were removed and fruit was harvested on September 23. The 1st, 2d, 3d, 4th, 8th, 12th, and 16th internodes were measured (table 7). The basal bud on the controls was considered to be the most basal one that had an interval of ½ inch or more between it and the next lower bud. Corresponding buds on the sprayed canes were used, although the distance to the next lower bud was often more than ½ inch in these cases.

Gibberellin usually increased internode lengths in proportion to the concentration used (table 7, fig. 16). Internodes on shoots sprayed at 1,000 ppm were about twice the length of the controls except for the 16th internode where the increase was much less (table 7).

A concentration of 100 ppm resulted in some longitudinal cracks, the smallest ones often having a diamond or canoe shape, and at 1,000 ppm many

typical longitudinal cracks occurred (fig. 17). A similar degree of injury occurred as a result of the second and third treatments.

Length of cluster parts was increased in proportion to the concentration used (table 8, fig. 18). At 10 ppm rather loose clusters resulted because the

TABLE 8

DATA AT HARVEST (SEPTEMBER 23) FOR ZINFANDEL CLUSTERS SPRAYED ON APRIL 7, APRIL 27, OR MAY 27 WITH GIBBERELLIN AT VARIOUS CONCENTRATIONS

Figures are averages of ten replicates

Treatment, concentration of gibberellin (ppm)	Length of cluster (cm)	Length of peduncle (cm)	Length of basal lateral of cluster (cm)	Length of pedicel (mm)	Weight per cluster (gm)	Weight per berry (gm)	Degree Balling reading	Total acid, per cent tartaric
Sprayed April 7								
0	16.6	0.9	10.1	6.3	385	2.16	21.0	0.66
1	18.3	1.2	12.4	....	418	2.00	22.0	0.69
10	20.8	1.7	14.4	8.9	335	1.64	21.0	0.64
100	25.5	2.4	15.2	12.2	188	....	22.3	0.59
1,000	....	3.0	....	16.1	9			
Sprayed April 27								
0	18.0	0.9	10.8	6.7	321	1.66	22.0	0.61
1	15.9	1.5	8.6	....	335	2.30	22.4	0.62
10	16.1	1.1	9.1	8.6	267	2.10	22.5	0.63
100	20.8	1.1	12.1	11.5	220	1.30	25.6	0.55
1,000	24.9	1.1	16.6	15.6	108	....	28.0	0.55
Sprayed May 27								
0	16.1	0.7	10.7	7.0	353	2.2	20.6	0.71
1	15.8	0.8	9.9	....	324	2.3	20.6	0.62
10	15.8	0.7	10.3	9.9	314	1.9	21.4	0.58
100	16.1	0.6	9.8	10.5	237	1.7	22.0	0.54
1,000	16.5	0.8	10.7	11.0	236	1.8	24.4	0.57
(1)*	1.04	0.3	N.S.	....	50			
(2)†	0.94	0.2	1.40	....	N.S.			

* L. S. D. at 5 per cent for concentrations on a given date of spraying.
† L. S. D. at 5 per cent for different spraying dates at a given concentration.

cluster parts were elongated. Very loose clusters resulted from the application of gibberellin at 100 ppm, but there were many shot berries (fig. 18). Clusters in the 1,000-ppm treatment were mostly dead and dry, and the rachises were cracked and crinkled. In this treatment pistils still adhered to the greatly elongated pedicels, and the cluster frameworks were quite brittle. The average weight per cluster and per berry usually decreased, and the number of small shot berries increased (table 8). There was no definite trend in the degree Balling readings or percentage of acid.

Results of Second Treatment (April 27). Elongation of shoots was accel-

erated by gibberellin (fig. 13). Applications made at both the second and third treatments hastened elongation of shoots as rapidly as did the first application (fig. 19). On May 9 clusters sprayed at 100 ppm had longer pedicels than those sprayed at lower concentrations, and flowering was beginning in clusters sprayed with regulator at 1,000 ppm (table 9). By May 22 almost all calyptras had fallen from clusters sprayed with gibberellin at 1,000 ppm. Some berries in this treatment were 4 mm in diameter, and their pedicels were much thickened. Concentrations of 100 or 1,000 ppm were much less toxic at the second than at the first treatment (fig. 20). On July 17 it was noted that higher concentrations resulted in advanced coloration.

TABLE 9

RANGE OF PEDICEL LENGTH AND RATE OF FLOWERING IN ZINFANDEL GRAPE SHOOTS SPRAYED ON APRIL 27 WITH GIBBERELLIN AT VARIOUS CONCENTRATIONS

Treatment, concentration of gibberellin (ppm)	May 9		May 17		May 22	
	Length of pedicels (mm)	Percentage of calyptras fallen	Length of pedicels (mm)	Percentage of calyptras fallen	Length of pedicels (mm)	Percentage of calyptras fallen
0	...	0	..	4–5	3–4	50
1	2-3	0	..	2	3–4	50
10	3–4	0	..	2	7–8	50
100	6–8	0	..	50	12–15	95
1,000	...	2	..	50	12–15	100*

* Some calyptras adhered as a result of heavy rain at bloom.

At harvest (September 26) measurements showed that gibberellin had little or no effect on elongation of the 1st to the 4th internodes, but that the 8th, 12th, and 16th internodes were much longer (table 7). The latter three internodes were about twice as long as corresponding controls in the 1,000-ppm treatment. Failure of older (more basal) internodes to elongate as a result of the second spraying would be expected, as these nodes were at least partially matured by time of treatment.

Length of cluster, basal lateral, and pedicels was usually increased in proportion to the concentration, but there was little effect on peduncle elongation (table 8). The increase in length of the basal laterals was, however, not significant. A concentration of 100 ppm caused some splitting and cracking of the rachis, although less than with corresponding clusters of the first treatment (fig. 18). Long, straggly clusters with many shot berries resulted from the 1,000-ppm treatment. Except for the concentration of 1 ppm, cluster weight was decreased by gibberellin applications. There is a strong indication that the degree Balling was increased and the percentage of acid decreased by some of the sprays (table 8).

Results of Third Treatment (May 27). At harvest (September 26) internode lengths measured showed little or no difference except at the 16th, where length was proprtionate to the concentration used (table 7). This internode on shoots sprayed at 1,000 ppm was about twice as long as the corresponding control internode.

Except for pedicels, cluster parts were not elongated (table 8, fig. 18). With the compound at 100 ppm, clusters were somewhat looser because pedicels were longer and berries smaller, but at 1,000 ppm the rachis was cracked and callused. The degree Balling reading was increased and the percentage of acid decreased at concentrations of 10, 100, or 1,000 ppm (table 8).

TABLE 10

EFFECT OF SPRAYS OF GIBBERELLIN APPLIED AT VARIOUS TIMES ON COLORATION OF ZINFANDEL GRAPES. PERCENTAGES INDICATE THE APPROXIMATE AMOUNT OF COLORATION OF TOTAL SURFACE OF FRUIT

Concentration of gibberellin (ppm)	Date of spraying			
	May 2	June 4	June 11	July 29
Observations on July 19				
	per cent	*per cent*	*per cent*	*per cent*
0	0	0	0.5	
0.1	0	0	0	
1	0	0.5	0.5	
5	0	1	0.5	
25	0	3	0.5	
Observations on July 29				
0	5	0.5	3	
0.1	5	1	1	
1	5	15	3	
5	7	25	10	
25	6	40	10	
Observations on August 7				
0	35	40	47	50
0.1	40	45	40	50
1	40	62	57	55
5	45	65	83	43
25	50	80	72	43

Spraying of Entire Vines. Vines were sprayed at each of four developmental stages with gibberellin at 0, 0.1, 1, 5, or 25 ppm, four vines per treatment. Early in May all shoots were pinched to prevent breakage by wind. The first series of vines was sprayed on May 2 when shoots ranged from 3 to 9 inches and clusters were ½–1½ inches long. This is the usual time for flower-cluster thinning (Winkler, 1931). A second series was treated on June 4 when clusters were at full bloom. A third treatment was made after the shatter of berries on June 11 when larger berries ranged from 5 to 6 mm in diameter. A final series was sprayed on July 29 when about 3 per cent of the total surface of fruit on unsprayed vines was colored and total soluble solids of colored berries amounted to about 15 per cent. These berries were about 13–14 mm in diameter.

Clusters sprayed at the first treatment (May 2) with concentrations of 5 or 25 ppm were beginning to flower by May 24. By May 28 the percentages of calyptras that had fallen from clusters sprayed at concentrations of 0, 0.1, 1, 5, or 25 ppm were about 10, 10, 20, 25, and 25 per cent, respectively, indicating that gibberellin hastened flowering. However, the first spraying had only a slight effect on hastening coloration of berries (table 10).

About 30 pounds of grapes were harvested from each vine on September 26. Many clusters were beginning to raisin, and there was considerable rot. The rotten parts of clusters were removed. Clusters sprayed with gibberellin at 25 ppm on May 2 were quite loose, as many shot berries had formed. The degree Balling reading was usually increased and the percentage of acid decreased by all levels of treatment (table 11).

TABLE 11

DATA AT HARVEST (SEPTEMBER 26) FOR ZINFANDEL GRAPES SPRAYED WITH GIBBERELLIN ON VARIOUS DATES

Figures are averages of four replicate vines

Treatment, concentration of gibberellin (ppm)	May 2		June 4		June 11		July 29	
	Degree Balling reading	Total acid, per cent tartaric	Degree Balling reading	Total acid, per cent tartaric	Degree Balling reading	Total acid, per cent tartaric	Degree Balling reading	Total acid, per cent tartaric
0	16.5	1.00	18.7	0.88	15.1	0.88	19.5	0.97
0.1	18.8	0.90	19.1	0.88	17.1	0.83	16.6	0.89
1	16.8	0.93	20.7	0.82	19.5	0.80	19.7	0.83
5	19.1	0.88	20.9	0.87	19.2	0.72	18.7	0.89
25	21.6	0.89	22.1	0.73	19.5	0.72	17.7	0.94

In July the second-crop clusters of vines sprayed on June 4 with gibberellin at 25 ppm had long pedicels and many shot berries (fig. 21). These clusters were young at the time of spraying and hence cluster parts were considerably elongated. Coloration of berries of the first-crop clusters sprayed on June 4 was hastened by concentrations from 1 to 25 ppm inclusive (table 10). At harvest clusters sprayed on June 4 with 5 or 25 ppm were quite loose because of the presence of shot berries. The foliage on these vines was less dense because of the longer shoots and internodes of this treatment. The degree Balling readings of fruit from vines sprayed on June 4 were increased by gibberellin (table 11).

At harvest (September 26) clusters sprayed at 5 and 25 ppm on June 11 were very compact. Cluster parts of the second crop were elongated, and there were many shot berries. Coloration was much advanced by the treatment on June 11 and degree Balling reading had increased (tables 10, 11).

The fourth treatment (July 29) had little effect on elongating cluster parts of either the first or second crop, and there was no definite effect on coloration, degree Balling, or percentage of acid (tables 10, 11).

Tokay

Because branches in the apical portions of Tokay clusters are relatively short, this portion of the cluster is compact after berry enlargement. Berry thinning is practiced to avoid this condition (Winkler, 1931). These experiments were designed to determine whether compactness can be avoided by elongating cluster parts, and also to note other responses of this variety to gibberellin.

Spraying of Young Shoots. Tokay shoots 1–2 inches long with four or five expanding leaves were sprayed with gibberellin at 0, 1, 10, 100, or 1,000 ppm

TABLE 12

DATA AT HARVEST (SEPTEMBER 27) FOR TOKAY GRAPES SPRAYED ON APRIL 27 WITH GIBBERELLIN

Lengths are averages of ten replicates.

Fruit combined for degree Balling and percentage of acid.

Concentration of gibberellin (ppm)	Length of cluster (cm)	Length of peduncle (cm)*	Length, second lateral from base (cm)	Degree Balling reading	Total acid, per cent tartaric
0	21.4	5.2	5.7	19.7	0.63
1	23.6	6.4	7.0	19.9	0.61
10	25.0	8.7	7.8	18.7	0.61
100	33.4	10.5	8.2	21.1	0.65
1,000	38.0	11.4	11.4	20.0	0.63

* Peduncle measured from base to second branch from base of cluster.

on April 27, ten shoots per treatment. On some shoots clusters were just beginning to emerge. On May 17 control shoots averaged 22.3 inches long, while those sprayed with gibberellin at 1,000 ppm averaged 27.9 inches; internodes, clusters, leaf petioles, and leaves were also longer in the treated shoots (fig. 22). Petioles of the fourth leaf from the basal end of control shoots were about 2 inches long, while corresponding petioles sprayed at 1,000 ppm were about 5 inches long. Leaf blades were about 4½ and 6 inches long, respectively. Most of the shoots sprayed at 1,000 ppm were broken off by the wind within three weeks. Flowering was hastened by the application of gibberellin. On May 21 the percentages of calyptras fallen from the 100- or 1,000-ppm treatments were 2 and 20 per cent, respectively, while none had fallen from the other treatments. At this time pedicel length was greatly increased, ranging from about 2 mm in the controls to 10–17 mm in clusters sprayed at 1,000 ppm. On May 21, clusters sprayed at 1 or 10 ppm appeared similar to the controls, but those sprayed at 100 or 1,000 ppm were long and straggly and had many shot berries.

Fruit was harvested on September 27. Length of cluster parts increased in proportion to the concentration used (table 12, fig. 23). The higher percentage of total soluble solids in clusters sprayed at 100 or 1,000 ppm may be partially due to the smaller weight per cluster resulting from the presence of shot berries.

Dipping of Flowering Clusters. Tokay clusters at full bloom were dipped in solutions of gibberellin at 0, 1, 5, 20, 100, or 500 ppm on May 27, 1957, ten clusters per treatment. At harvest on September 30 control clusters were compact, and about 60 per cent of the total surface of the fruit was colored. Treatment at 1, 5, or 20 ppm resulted in enough shot berries to loosen up the clusters (fig. 24). Many of these shot berries were as fullly colored as the seeded berries. Concentrations of 100 or 500 ppm were excessive as indicated by the large number of shot berries (fig. 24). Many of these berries were somewhat elongated. The data (table 13) indicate that with the exception of the second lateral from the base, cluster parts were not elongated. Full bloom is evidently too late for treatment to bring about sufficient elongation of all cluster parts in Tokay. The average weight per cluster and average berry weight were smaller in dipped clusters than in the control. No consistent differences were obtained in the degree Balling reading or percentage of acid (table 13).

TABLE 13

DATA AT HARVEST (SEPTEMBER 30) FOR TOKAY CLUSTERS DIPPED ON MAY 27 IN SOLUTIONS OF GIBBERELLIN

Figures are averages of ten clusters

Concentration of gibberellin (ppm)	Length of cluster (cm)	Length of peduncle (cm)*	Length, second lateral from base (cm)	Weight per cluster (gm)	Weight per berry (gm)	Degree Balling reading	Total acid, per cent tartaric
0	24.8	2.4	5.9	624	3.53	17.5	0.51
1	22.8	....	7.2	437	3.28	21.1	0.52
5	21.6	1.9	5.9	358	3.41	17.0	0.54
20	21.6	2.1	6.8	350	2.71	17.8	0.55
100	25.2	2.3	7.7	410	2.58	18.0	0.54
500	24.1	2.4	8.1	477	2.84	19.4	0.50

* Peduncle measured from base to basal branch of cluster.

TABLE 14

DATA AT HARVEST (OCTOBER 21) FOR TOKAY GRAPES SPRAYED WITH GIBBERELLIN ON THREE DIFFERENT DATES

Concentration of gibberellin (ppm)	Sprayed June 6		Sprayed June 14		Sprayed August 7	
	Degree Balling reading	Total acid, per cent tartaric	Degree Balling reading	Total acid, per cent tartaric	Degree Balling reading	Total acid, per cent tartaric
0	20.8	0.66	20.3	0.62	21.3	0.72
0.1	21.2	0.56	21.2	0.79	22.9	0.77
1	22.5	0.56	22.1	0.72	20.1	0.80
5	22.0	0.61	21.9	0.62	21.9	0.60
25	20.1	0.60	20.8	0.56	20.3	0.69

Spraying of Entire Vines. Tokay vines were sprayed with gibberellin at 0.1, 1, 5, or 25 ppm on three different dates, four vines per treatment. The first series of vines was sprayed on June 6 at the end of flowering, but before

any shatter had occurred. When the second series of vines was treated on June 14, shatter was complete, and the larger berries were about 8 mm in diameter. The final series was sprayed on August 7 when coloration was just beginning, and the degree Balling reading was about 14.

At harvest (October 21) a 50-pound sample was taken from each plot for analysis. There was considerable rot in the fruit as a result of frequent early rains. Clusters sprayed at 25 ppm on June 6 had some shot berries, but those of all other treatments were comparable to the controls (fig. 25). The applications made on June 6 or June 14 usually resulted in a slight increase in the degree Balling reading (table 14).

TABLE 15

DATA AT HARVEST (SEPTEMBER 17) FOR RIBIER GRAPES DIPPED IN GIBBERELLIN AT FULL BLOOM

Concentration of gibberellin (ppm)	Degree Balling reading	Total acid, per cent tartaric
0	16.7	0.63
1	17.2	0.54
5	16.2	0.55
20	17.0	0.58
100	18.0	0.54
500	17.2	0.52

Ribier

Experiments were conducted to determine the effect of gibberellin on set and maturation of the fruit. Compactness is not a problem in this variety.

Dipping Experiment. Clusters at full bloom were dipped on May 27 in various concentrations of gibberellin, ten clusters per treatment (table 15). Fruit was harvested on September 17. No beneficial results were obtained in this experiment. The lower concentrations (1 and 5 ppm) caused some shot berries. Higher concentrations (100 and 500 ppm) were too toxic; many shot berries and straggly clusters resulted (fig. 26). A concentration of 500 ppm produced crooked and twisted rachises. Fruit from each treatment was combined for must analyses (table 15). There were no consistent differences in degree Balling or percentage of acid.

Spraying of Entire Vines. Ribier vines were sprayed on four different dates with gibberellin at 0, 0.1, 1, 5, or 25 ppm, four vines per treatment. The first series of vines was treated on May 6 when shoots averaged 20 inches long and clusters about 6 inches, excluding the peduncles. When the second series was sprayed on May 27, vines were at full bloom, and on June 11, when the third series was treated, berry shatter was complete. The final series was treated on August 7 when about 15 per cent of the total surface of the fruit was colored, and the colored berries had a degree Balling reading of about 13.5.

Clusters sprayed at 5 or 25 ppm were beginning to flower by May 21. Three days later the percentages of calyptras that had fallen from clusters sprayed at 0, 0.1, 1, 5, or 25 ppm were about 0.2, 8, 6, 10, and 10 per cent,

respectively, showing that flowering had been hastened. The first spraying had little effect on coloration of berries (table 16). The slightly advanced coloration in the 5 and 25 ppm treatments, observed on August 14, may have been a result of lower cluster weight, caused in turn by the presence of many shot berries. Smaller cluster weight is not reflected in smaller berry weight, as very small shot berries were not included in the determination of berry size (table 17).

At harvest on October 3, clusters sprayed at 1 or 5 ppm on May 6 had a few shot berries, while those treated at 25 ppm had many (fig. 27). The first spraying had little effect on the percentage of total soluble solids or percentage of acid.

TABLE 16

EFFECT OF SPRAYS OF GIBBERELLIN ON COLORATION IN RIBIER GRAPES

Figures are percentages of total surface of fruit colored

Concentration of gibberellin (ppm)	Date of spraying			
	May 6	May 27	June 11	August 7
Observations made August 5				
0	2	2	2	..
0.1	3	4	2	..
1	2	3	5	
5	1	8	10	
25	5	10	12	.
Observations made August 14				
0	35	35	35	30
0.1	35	35	35	35
1	35	35	40	30
5	40	35	40	35
25	40	40	45	35

Observations made on August 5 showed that coloration had been somewhat hastened by the May 27 spraying (table 16). Mature fruit from the second spraying was comparable to that of the first. An increase in the percentage of total soluble solids resulted from concentrations of 1–25 ppm.

Spraying on June 11 caused some advance in coloration (table 16). At harvest clusters sprayed with gibberellin at 25 ppm were less compact than the controls, and the percentage of total soluble solids was higher on sprayed vines (table 17).

The fourth spraying slightly increased the degree Balling readings, but otherwise these clusters were similar to the untreated controls.

Red Malaga

The fruit of this variety, like Ribier, is not compact, so elongation of cluster parts is not desirable.

Red Malaga vines were sprayed with gibberellin at 0, 0.1, 1, 5, or 25 ppm at four stages of development, four vines per treatment. The early growth of the shoots was very uneven. When the first series of vines was treated, on

TABLE 17

DATA AT HARVEST (OCTOBER 3) FOR RIBIER GRAPES SPRAYED WITH GIBBERELLIN ON VARIOUS DATES

Figures are averages of four replicate vines

Treatment, concentration of gibberellin (ppm)	Weight per cluster (gm)	Weight per berry (gm)	Degree Balling reading	Total acid, per cent tartaric
Sprayed May 6				
0	581	6.89	17.2	0.47
0.1	576	7.22	17.1	0.47
1	490	7.20	17.2	0.50
5	422	6.86	17.2	0.51
25	313	6.89	18.4	0.56
Sprayed May 27				
0	513	6.83	17.3	0.46
0.1	490	6.62	17.4	0.46
1	395	6.51	19.3	0.44
5	340	7.04	19.6	0.53
25	181	5.30	22.1	0.44
Sprayed June 11				
0	472	6.64	17.7	0.45
0.1	358	6.39	19.2	0.43
1	440	6.79	18.4	0.43
5	494	7.45	18.7	0.52
25	340	5.57	19.5	0.53
Sprayed August 7				
0	377	7.00	17.4	0.46
0.1	535	7.63	18.3	0.53
1	458	7.31	18.8	0.48
5	476	6.49	18.4	0.46
25	517	6.46	18.1	0.54
(1)*	54	0.45	0.95	
(2)†	50	0.22	0.90	

* L. S. D. at 5 per cent for concentrations on a given date of spraying.
† L. S. D. at 5 per cent for different spraying dates at a given concentration.

May 3, length of shoots ranged from 1 to 8 inches, and clusters were about 1 inch long. At the second treatment, June 4, clusters were in full bloom. Shatter of berries was complete on June 14, date of treatment for the third series. When the fourth series was sprayed, on July 29, coloration was just beginning, and total soluble solids in colored berries amounted to about 15 per cent.

Six days after the first spraying, clusters sprayed at 25 ppm were much larger than the control clusters. By May 28 about 10 per cent of the calyptras had fallen from these clusters, while only about half that number had fallen from controls or other treatments. Coloration was hastened by the 25-ppm spray applied on May 3 (table 18). At harvest, September 6, clusters sprayed at 5 or 25 ppm had many shot berries (fig. 28). There was little effect on berry size, degree Balling reading, or percentage of acid from the first treatment (table 19).

TABLE 18

EFFECT OF SPRAYS OF GIBBERELLIN ON COLORATION OF RED MALAGA GRAPES

Figures are percentages of total surface of fruit colored

Concentration of gibberellin (ppm)	Date of spraying			
	May 3	June 4	June 14	July 29
	Observed July 26			
0	0	0	0	..
0.1	0	0	0	..
1	0	0	0	..
5	0	0	0	..
25	3	1	0	..
	Observed August 5			
0	3	4	2	3
0.1	4	2	3	3
1	4	7	2	3
5	4	12	4	3
25	30	25	13	3

Coloration was advanced as a result of gibberellin applied on June 4 (table 18). At harvest there were a few shot berries resulting from the 1-ppm sprays and many from the 5-ppm sprays; with 25 ppm there were so many that clusters were very straggly (fig. 28). Many more shot berries resulted from the second treatment (full bloom) than from the first (fig. 29). Average berry size was much smaller as a result of spraying at 25 ppm, which caused many shot berries, and there is an indication that the degree Balling is increased by the second spraying (table 19).

The 25-ppm spray applied on June 14 may have hastened ripening (tables 18, 19). At harvest very few shot berries were present in the clusters of the June 14 treatment.

Coloration of clusters of the final treatment (August 14) was not advanced, and at harvest all clusters resembled the control fruit (tables 18, 19).

Muscat of Alexandria

Since this variety often produces a very poor set of fruit, an experiment was run to determine whether gibberellin could improve the set. On May 30 flowering clusters of Muscat of Alexandria were dipped in gibberellin at

0, 1, 5, 20, 100, or 500 ppm, five clusters per treatment. Fruit was harvested on September 20. Control clusters had made an excellent set (fig. 30). In this experiment set was not increased by any treatment; in fact, there were

TABLE 19

DATA AT HARVEST (SEPTEMBER 6) FOR RED MALAGA GRAPES SPRAYED WITH GIBBERELLIN ON ONE OF FOUR DIFFERENT DATES

Treatment, concentration of gibberellin (ppm)	Weight per berry (gm)	Degree Balling reading	Total acid, per cent tartaric
Sprayed May 3			
0	4.48	19.2	0.50
0.1	4.37	20.2	0.55
1	4.68	19.2	0.52
5	4.33	19.6	0.54
25	4.10	19.4	0.56
Sprayed June 4			
0	4.27	19.4	0.58
0.1	4.28	20.5	0.59
1	4.12	21.1	0.59
5	4.03	20.3	0.60
25	3.13	22.0	0.54
Sprayed June 14			
0	4.35	19.3	0.53
0.1	3.98	19.7	0.60
1	4.35	19.0	0.52
5	4.20	19.7	0.52
25	3.73	21.6	0.51
Sprayed August 29			
0	4.16	19.8	0.61
0.1	3.94	20.0	0.61
1	4.01	20.1	0.56
5	4.18	19.1	0.58
25	4.52	18.6	0.56

more shot berries in most treated clusters than in the controls. Some berries treated with concentrations of 20, 100, or 500 ppm were slightly elongated (fig. 30).

DISCUSSION

Treatment of flowering clusters of Black Corinth with gibberellin resulted in an excellent set of much larger berries than previously produced by 4-chlorophenoxyacetic acid at Davis, California (Weaver, 1956). The berries were also considerably elongated, an effect which is not produced by 4-chlorophenoxyacetic acid or girdling alone.

Application of gibberellin to Thompson Seedless grapes resulted in berries much larger than those produced by girdling alone. The use of 4-chlorophenoxyacetic acid in some locations had previously produced berries just as large as girdling, but rarely were they larger (Weaver, 1956). In future experiments it would be desirable to apply gibberellin in conjunction with girdling as was previously done with 4-chlorophenoxyacetic acid (Weaver, 1956).

Enlargement of berries in seedless fruit (Black Corinth and Thompson Seedless) is one of the most significant responses of grapes to gibberellin. This might indicate that the native supply of gibberellin or related compounds in seedless fruit is low. The response of seeded berries to the regulator was much less than that of seedless. Perhaps seeds produce sufficient gibberellin or related compounds to result in almost maximum berry enlargement. Phinney *et al.* (1957) demonstrated the presence of a "gibberellin-like" substance in several seeds. In this connection it is of interest that Rappaport (1957) applied gibberellin to developing tomato fruit but failed to increase fruit size.

Length of shoots and internodes was greatly increased by applications of gibberellin. The basal internodes of Zinfandel were elongated when shoots were sprayed at very young stages of development. At later stages internodes farther toward the shoot tip were elongated, but basal ones were not. This would indicate that it is the young meristematic internode tissue that is most responsive to the regulator. Elongation of basal internodes would be very undesirable in both spur- and cane-pruned vines, as the vines would tend to grow rapidly out of shape. In these experiments shoot elongation of Zinfandel was accelerated by applications made on April 7, April 27, or May 27. Response of vines to applications made later in the season should be studied.

It is desirable to apply gibberellin before time of bloom in order to elongate cluster parts. Young clusters are very responsive to the regulator. Accompanying the elongation of cluster parts, however, is the development of shot berries, which are deleterious in table grapes but not necessarily a defect in wine grapes. However, proper concentrations and times of application may produce looser clusters with few or no shot berries. It is of interest that Winkler (1931) increased the size of younger flower clusters more than older ones by flower-cluster thinning. Before gibberellin came into use, thinning was the only known means of increasing size of cluster parts.

Gibberellin has been shown by many investigators to have a wide range of effective concentrations for a number of crops (Lindstrom *et al.*, 1957; Marth *et al.*, 1956; Wittwer and Bukovac, 1957). This is also true with grapes. Even concentrations of 1,000 ppm have failed to kill shoots, although in Zinfandel the young clusters were killed. Fruitful parts are apparently more susceptible to injury from high concentrations of gibberellin than are the vegetative parts. Perhaps gibberellin applied around full bloom would be an excellent thinning agent, since suitable concentrations arrest development of some berries while doing no great harm to the shoots (Weaver, 1954). In seeded grapes, for example, when gibberellin was applied at full bloom at 25 ppm, many berries failed to enlarge, and as a result clusters were loose.

Gibberellin sprays at 100 or 1,000 ppm caused shoots to become cracked and callused, although they were not killed. Longitudinal splitting of bark, spur shoots, and branches one year old or older has also been noted in apricot (Bradley and Crane, 1957).

In some varieties gibberellin definitely hastened flowering, as well as coloration and an increase in degree Balling reading. Earlier flowering may have been partially instrumental in hastening ripening, but the compound probably also accelerated metabolic processes in the growing berries. It is also possible that in some cases the faster ripening (especially where high concentrations were applied) was a result of decreased crop weight due to the presence of shot berries. Cropping has been shown to have a profound effect on depressing both coloration and degree Balling (Weaver *et al.*, 1957).

One of the striking effects gibberellin has on grapes, as well as other plants, is the stimulation of shoot elongation which may result in the production of more wood. Experiments must be carried on over a period of years to determine whether increased vegetative growth will eventually weaken the vine. The carbohydrate nutrition of these vines, as compared with unsprayed vines, should also be studied. Of special importance would be changes in food reserves (starches and sugars) in the roots.

The production of longer shoots as a result of gibberellin applications may or may not be disadvantageous. The translocation experiment in the Thompson Seedless indicated that when the high concentration of 1,000 ppm was applied only to basal portions of shoots, the amount of elongation was much less than when the whole shoot was sprayed. Perhaps with lower concentrations even less stimulation would occur. When single shoots were sprayed, there was apparently little translocation to adjacent shoots, as indicated by stimulation of shoot elongation. More detailed experiments are needed on the translocation of gibberellin in grapes. It has been shown to be readily translocated in tomato plants (Person and Rappaport, 1958).

SUMMARY

The response of Black Corinth, Thompson Seedless, Zinfandel, Tokay, Ribier, Red Malaga, and Muscat of Alexandria grapes to gibberellin was studied. Within two or three days after treatment, foliage and stems turned yellowish, the color becoming more intense with higher concentrations. After several days, however, the tissues again became green. In all varieties shoot growth was stimulated and internodes were elongated.

Dipping of clusters and spraying of Black Corinth vines showed that gibberellin applied in concentrations ranging from 5 to 500 ppm resulted in an excellent set of large berries. At the higher concentrations, berries were elongated.

Individual shoots of Thompson Seedless were sprayed at three developmental stages with gibberellin in concentrations ranging from 1 to 1,000 ppm. Spraying of shoots at the two earlier developmental stages (shoots 7–9 inches long) at concentrations of 100 or 1,000 ppm usually hastened flowering and increased elongation of clusters and peduncles. However, the clusters were quite straggly because many shot berries occurred. Applications at full

bloom in the range from 10 to 1,000 ppm resulted in large clusters with large, elongated berries.

Fruit from ungirdled Thompson Seedless vines was berry-thinned and the vines were sprayed with gibberellin at 5, 20, or 50 ppm after berry shatter. Berry size was greatly increased, and at 20 and 50 ppm larger berries resulted than from girdling alone. Thickened pedicels developed in the sprayed vines. In another experiment Thompson Seedless was sprayed in the range of 0.1 to 25 ppm, applied at four stages of development. Berry size was increased by the compound at 1 to 25 ppm applied at full bloom or after berry shatter, and possibly by 5 and 25 ppm when total soluble solids amounted to about 15 per cent.

A translocation study with Thompson Seedless showed that gibberellin is readily translocated from basal leaves to apical parts of shoot.

Zinfandel shoots were sprayed with gibberellin in concentrations ranging from 1 to 1,000 ppm on April 7, April 27, or May 27. Each treatment greatly stimulated shoot elongation, and on July 15 shoots sprayed with 1,000 ppm on April 7 were about twice as long as those of the controls. Basal internodes of Zinfandel shoots were elongated when shoots were sprayed on April 27 (shoots 2–3 inches long), but at the later stages only internodes farther toward the shoot tips were elongated. Longitudinal splitting and cracking occurred in shoots sprayed at 100 or 1,000 ppm. Flowering was hastened by the first two applications, and elongation of cluster parts was greatly accelerated as a result of the first spraying. The 10-ppm treatment applied on April 7 resulted in rather loose clusters, but at higher concentrations many shot berries developed. There was less elongation of cluster parts as a result of the second treatment and little or none from the third.

Zinfandel vines were sprayed with gibberellin in concentrations ranging from 0.1 to 25 ppm at four developmental stages. The spraying on June 4 (full bloom) and June 11 (berry set) resulted in advanced coloration and probably a higher percentage of total soluble solids. At harvest, clusters sprayed at full bloom with the compound at 5 to 25 ppm were quite loose because of shot berries. This suggests that gibberellin may be of value as a thinning agent.

Young Tokay shoots sprayed with gibberellin produced larger leaves and elongated cluster parts. However, elongation was accompanied by development of many shot berries. Dipping of Tokay clusters at full bloom failed, with one exception, to elongate cluster parts. There was an indication that when Tokay vines were sprayed on June 6 or June 14 the degree Balling reading was higher by harvest time.

When flowering clusters of Ribier were dipped, no beneficial effects resulted. Ribier vines were sprayed at four developmental stages with concentrations ranging from 0.1 to 25 ppm. Coloration was slightly hastened by all sprayings, and degree Balling readings, as well as number of shot berries, were higher in vines sprayed at the last three stages.

The spray experiment with Ribier was repeated with Red Malaga, with generally similar results. Dipping of flowering clusters of Muscat of Alexandria in solutions of gibberellin failed to increase the percentage of set.

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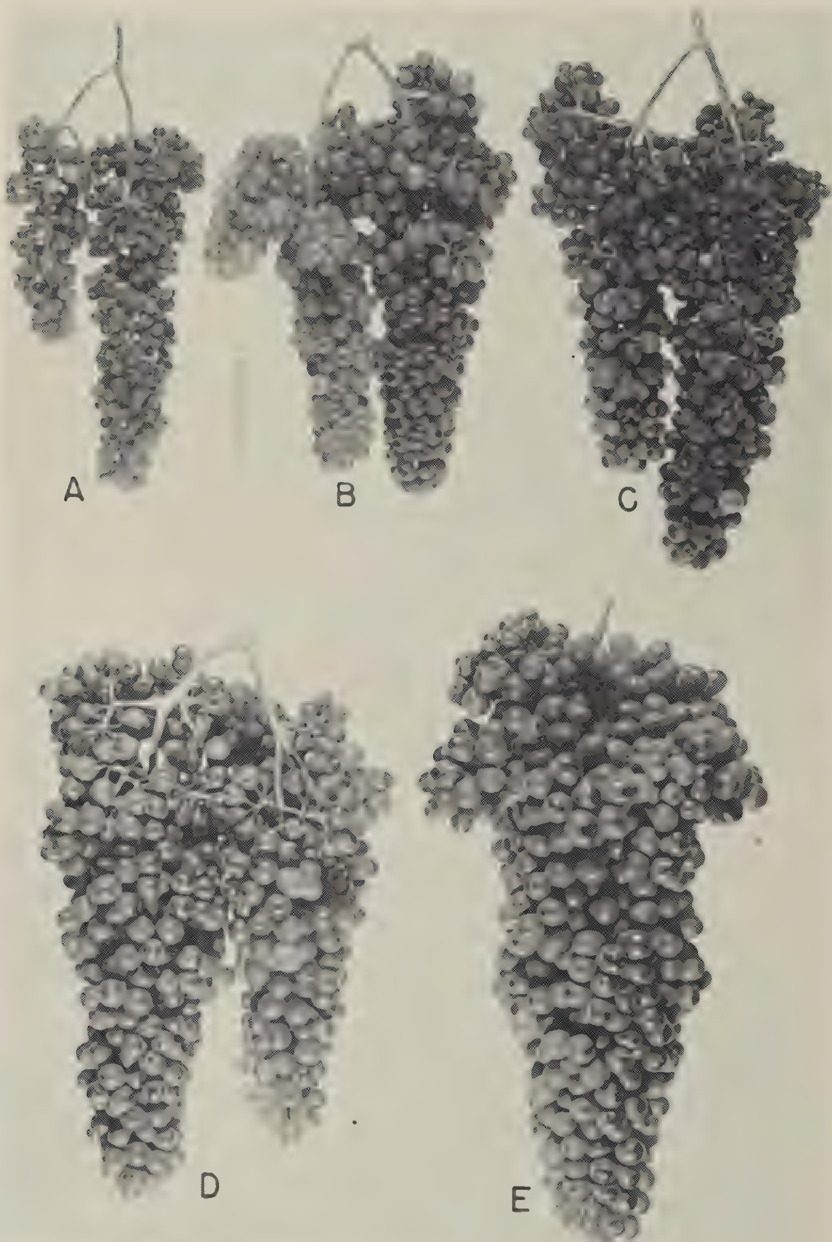


Fig. 1. Black Corinth clusters 59 days after being dipped in gibberellin on May 31 at 1 (*C*), 20 (*D*), or 500 ppm (*E*). Untreated control, *A*. Girdled but not dipped cluster (*B*) was taken from an adjacent girdled vine. The compound at 1 ppm resulted in a loose cluster. Note large oval berries resulting from compound at 100 (*D*) or 500 ppm (*E*). Photographed July 29, 1957.

Fig. 2. Portions of clusters of Black Corinth 59 days after being dipped on May 31 in gibberellin at 500 ppm (right). Cluster from adjacent girdled vine, left, with some berries removed to expose rachis, laterals, and pedicels. Note that laterals on dipped cluster (right) are two or three times larger than those of girdled cluster. Photographed July 30, 1957.

Fig. 3. Berries from Black Corinth clusters 59 days after being dipped in gibberellin at 500 ppm (*A*). Undipped berries from adjacent girdled vine (*B*), and untreated controls (*C*). Note large, elongated berries and thickened pedicels on dipped berries. Photographed July 30, 1957.

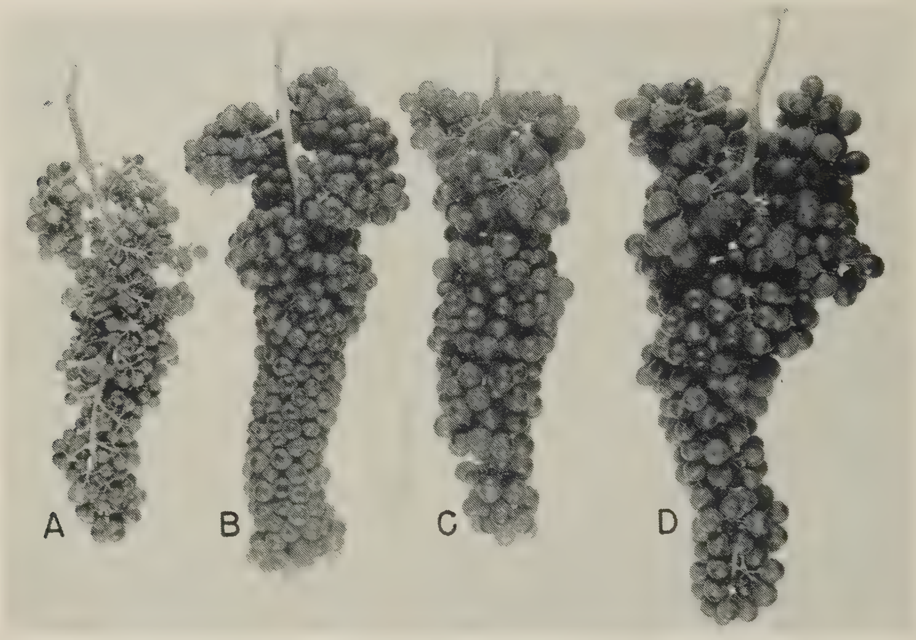


Fig. 4. Black Corinth grapes 59 days after being sprayed on May 31 with gibberellin at 5 (*C*) or 20 ppm (*D*). Control (*A*), and girdled but unsprayed (*B*). Berries sprayed at 5 ppm are larger than girdled but unsprayed berries, but those sprayed at 20 ppm are largest. Photographed July 30, 1957.

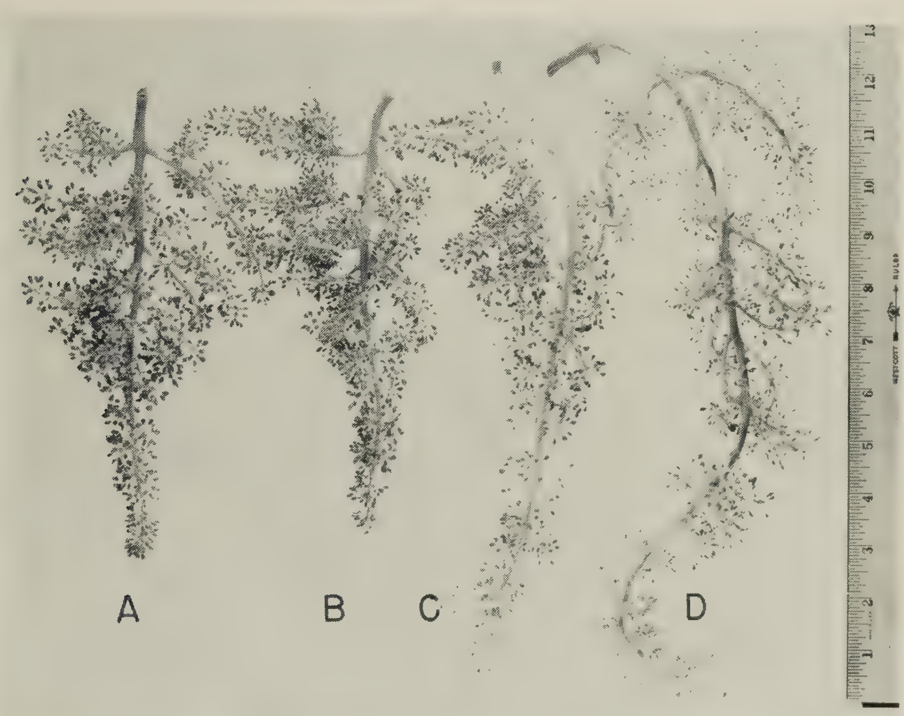


Fig. 5. Thompson Seedless clusters 39 days after shoots were sprayed on April 23 with gibberellin at 0 (*A*), 10 (*B*), 100 (*C*), or 1,000 ppm (*D*). Note that concentrations of 100 (*C*) and 1,000 (*D*) ppm produced elongated clusters and pedicels. Note that all calyptras have fallen from the cluster treated at 1,000 ppm (*D*). Photographed May 31, 1957.

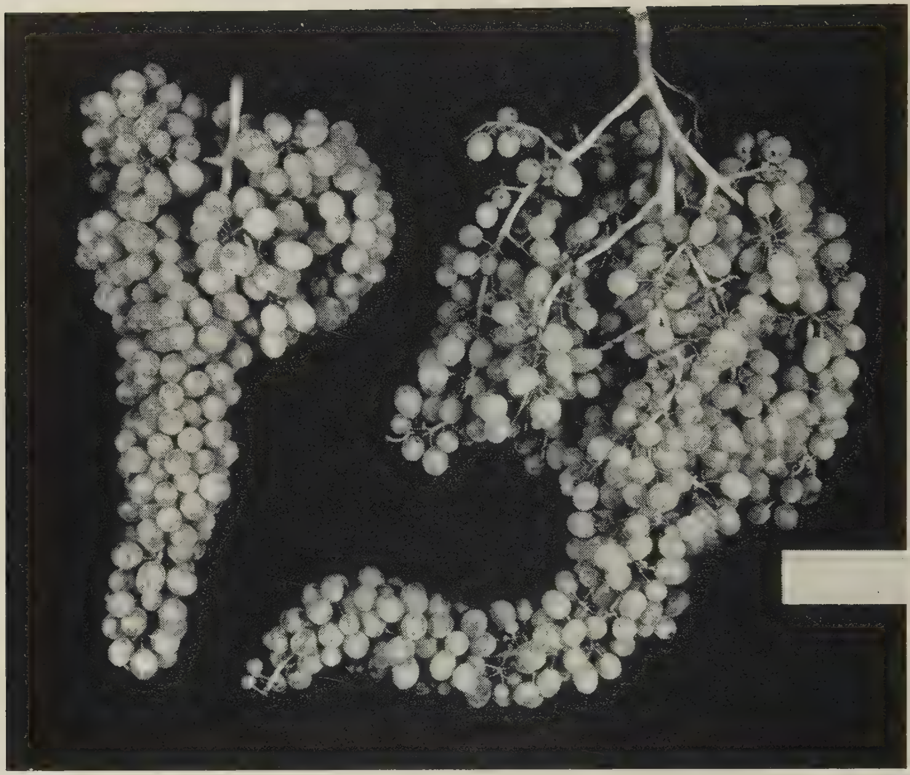


Fig. 6. Thompson Seedless grapes 125 days after shoots were sprayed on April 23 with gibberellin at 1,000 ppm (right). Control, left. Sprayed cluster is much elongated, but there are many shot berries. Photographed August 29, 1957.

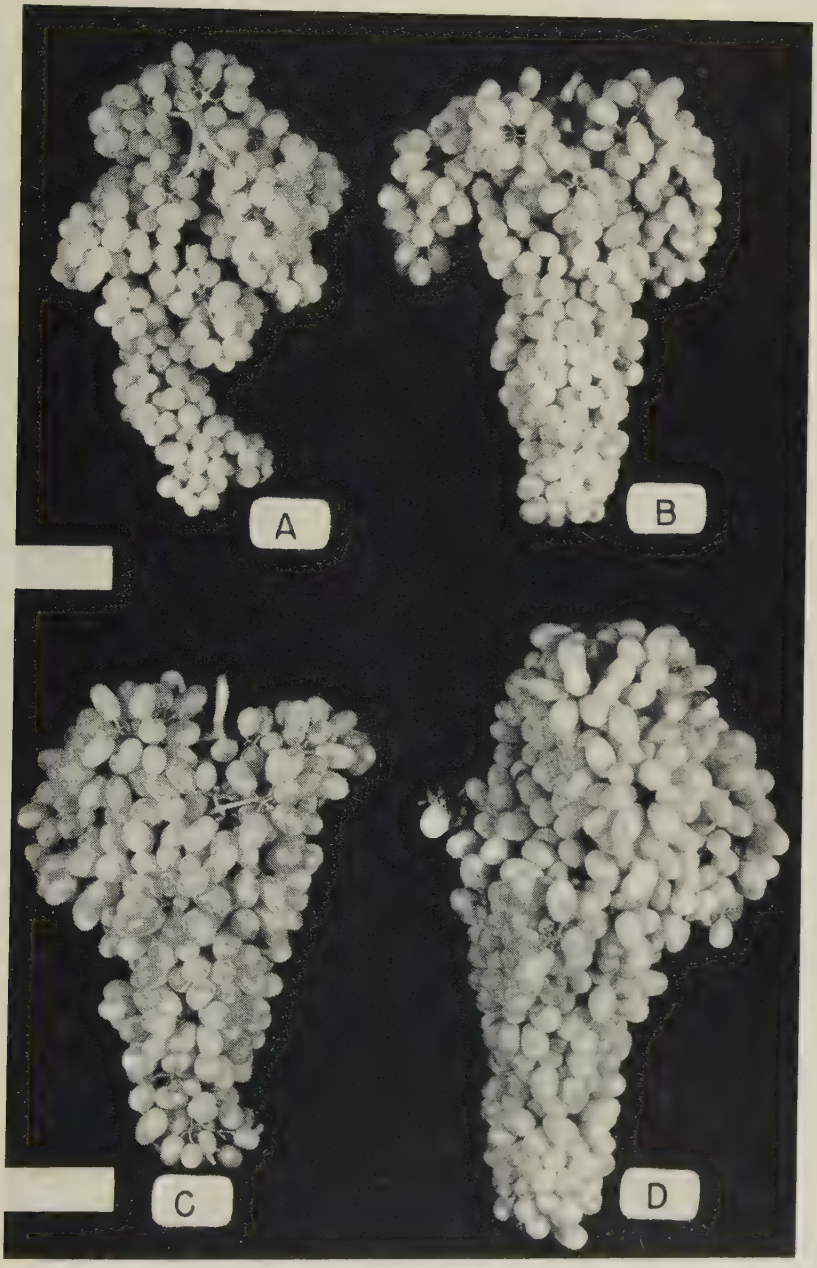


Fig. 7. Thompson Seedless grapes 89 days after being sprayed with gibberellin at 0 (*A*), 10 (*B*), 100 (*C*), or 1,000 (*D*) ppm at full bloom on May 29. Note that sprayed clusters have larger and elongated berries. Photographed August 30, 1957.

Fig. 8. Close-up of berries of Thompson Seedless 89 days after being sprayed at full bloom on May 29 with gibberellin at 0 (*A*), 10 (*B*), 100 (*C*), or 1,000 ppm (*D*). Note that berries are larger and more elongated and pedicels are thicker as the concentration increases. Photographed August 29, 1957.

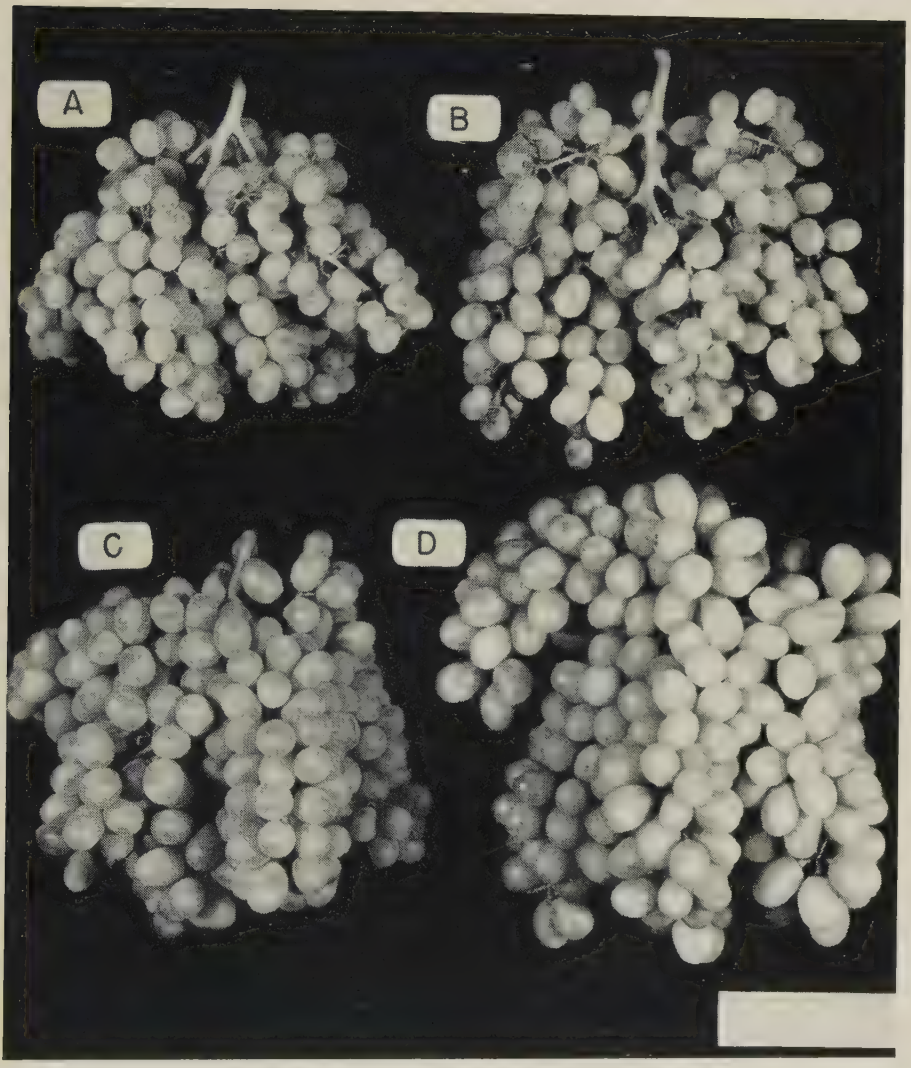


Fig. 9. Thompson Seedless grapes 76 days after being sprayed on June 11 with gibberellin at 5 (*B*), 20 (*C*), or 50 ppm (*D*). Ungirdled, unsprayed (*A*). Note that berry size increases with higher concentrations, and that some berry elongation occurs with higher concentrations. Photographed August 29, 1957.

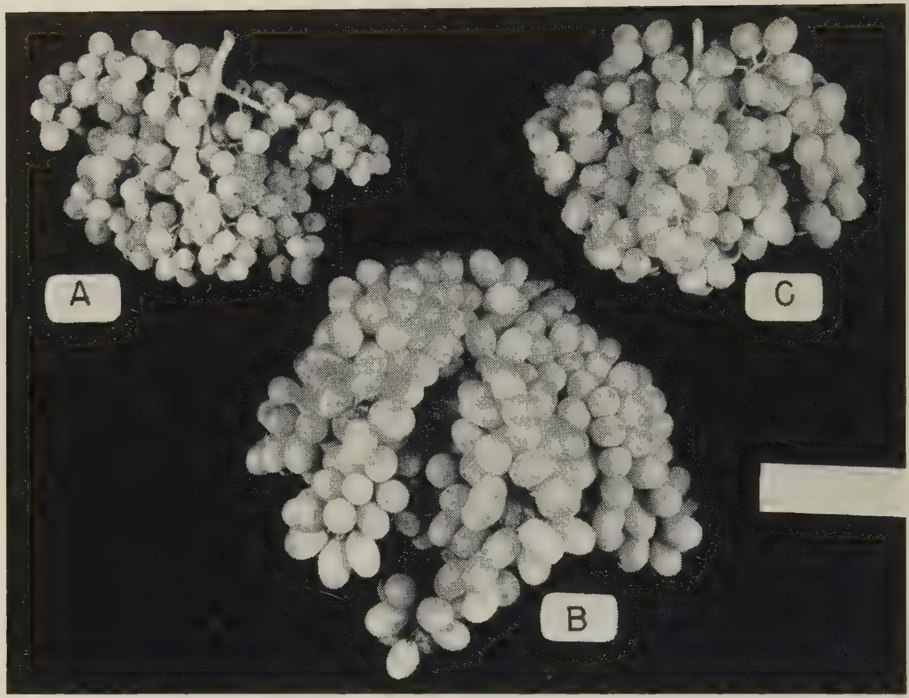


Fig. 10. Thompson Seedless grapes 76 days after being sprayed on June 11 with gibberellin at 50 ppm (*B*). Ungirdled, unsprayed (*A*), and girdled, unsprayed (*C*). Note that sprayed berries are much larger than the girdled, and that the controls are the smallest. Photographed August 29, 1957.

Fig. 11. Lateral branches from near center of clusters of Thompson Seedless grapes 76 days after being sprayed on June 11 with gibberellin at 50 ppm, right. Control, left. Note thicker pedicels and larger berries on the sprayed laterals. Photographed August 29, 1957.

Fig. 12. Zinfandel shoots 16 (top) and 50 days (bottom) after certain shoots were sprayed with gibberellin at 1,000 ppm on April 7. Note great length of treated shoots. Photographed on April 23 and May 27, 1957, respectively.

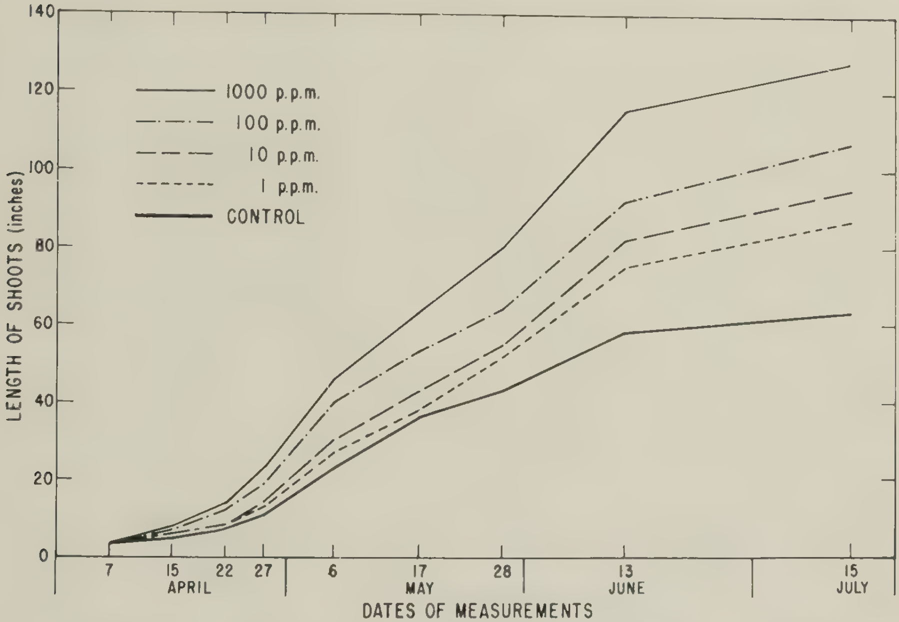


Fig. 13. Elongation of Zinfandel shoots sprayed with gibberellin on April 7. Note that even a concentration of 1 ppm resulted in longer shoots, and that shoots sprayed at 1,000 ppm were about twice the length of untreated controls on July 15.

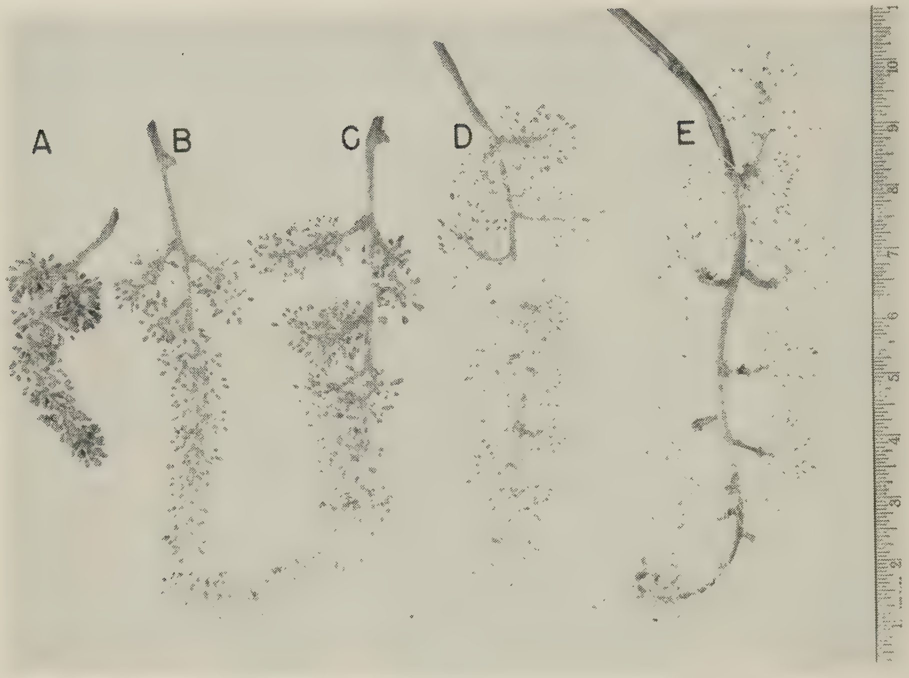


Fig. 14. Clusters of Zinfandel 44 days after spraying on April 7 with gibberellin at 0 (*A*), 1 (*B*), 10 (*C*), 100 (*D*), or 1,000 ppm (*E*). Note that treatment has hastened flowering and resulted in longer pedicels. Gibberellin at 1,000 ppm has caused splitting of the peduncle and twisting of the rachis and its laterals. Wings of cluster have been removed. Photographed May 21, 1957.

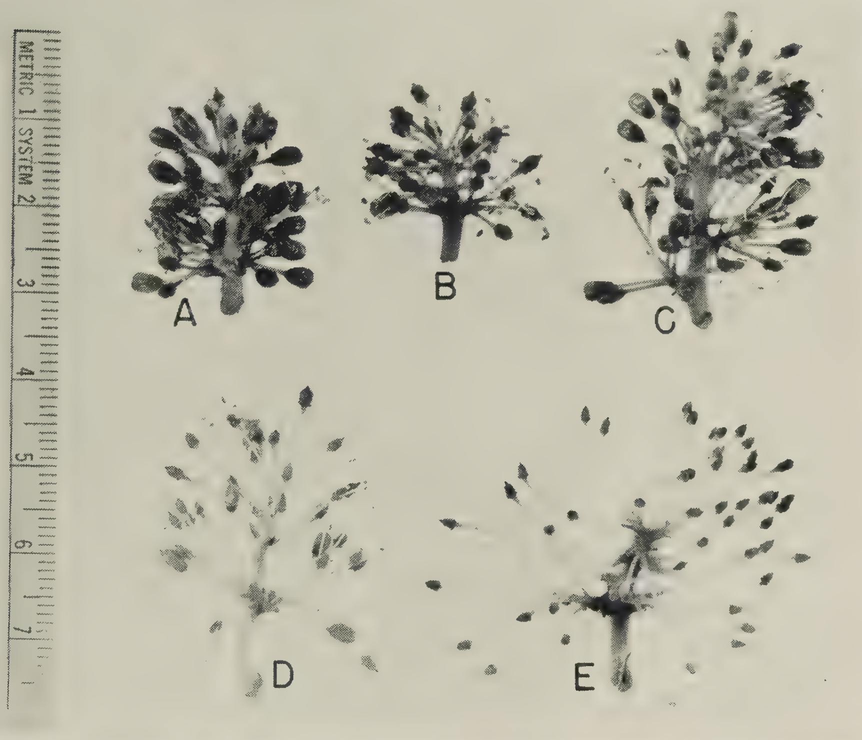


Fig. 15. Close-up of third lateral from basal end of Zinfandel clusters 44 days after being sprayed on April 7 with gibberellin at 0 (*A*), 1 (*B*), 10 (*C*), 100 (*D*), or 1,000 ppm (*E*). Note that with increasing concentrations pedicels are longer and flowering is hastened. Photographed May 21, 1957.

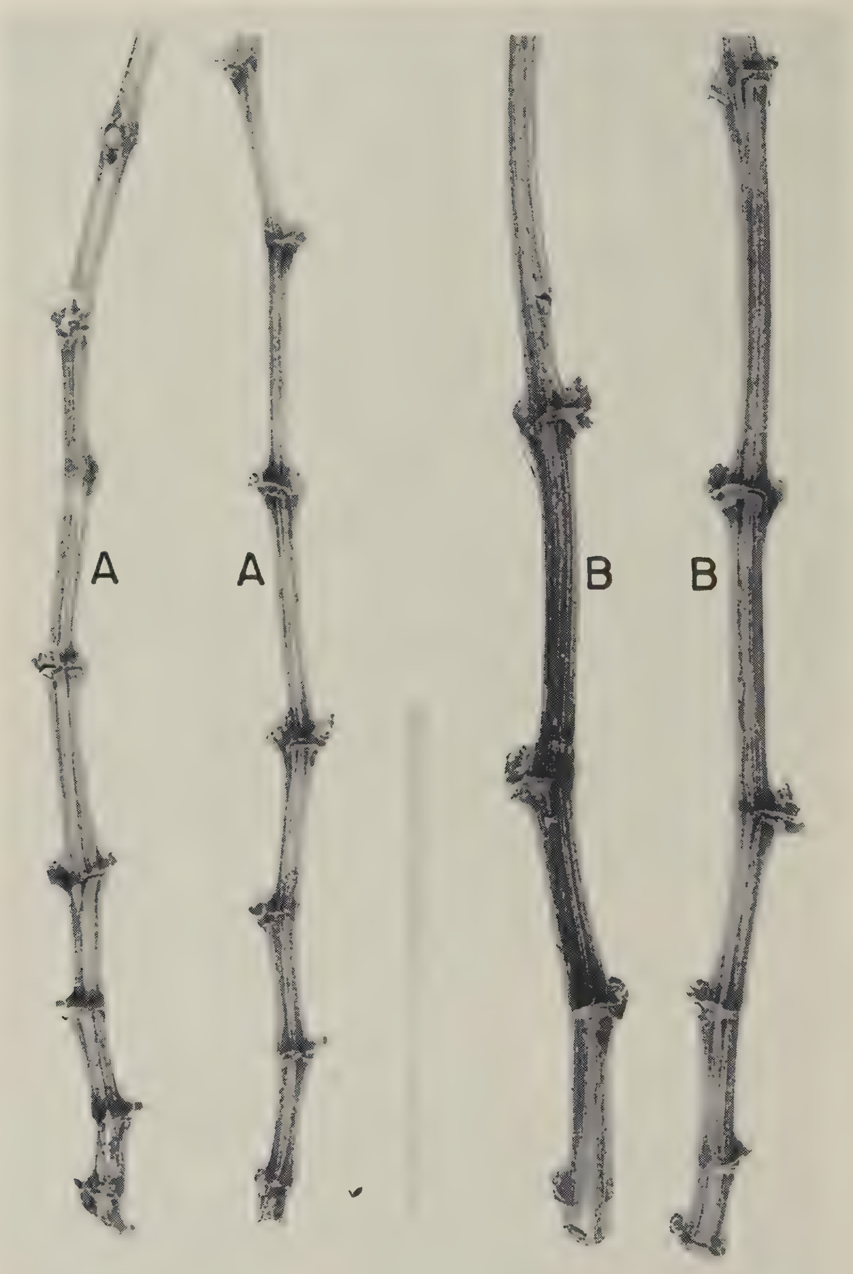


Fig. 16. Basal portions of Zinfandel shoots at harvest 169 days after being sprayed on April 7 with gibberellin at 100 ppm (*B*). Controls (*A*). Leaves removed to expose internodes. Note that internodes on sprayed shoots (*B*) are much longer than those of controls (*A*). Photographed September 24, 1957.

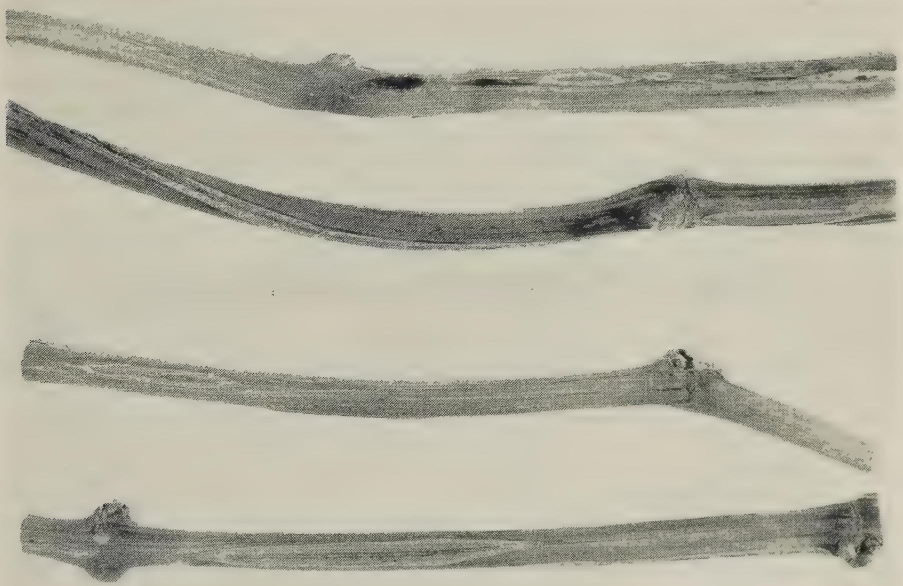
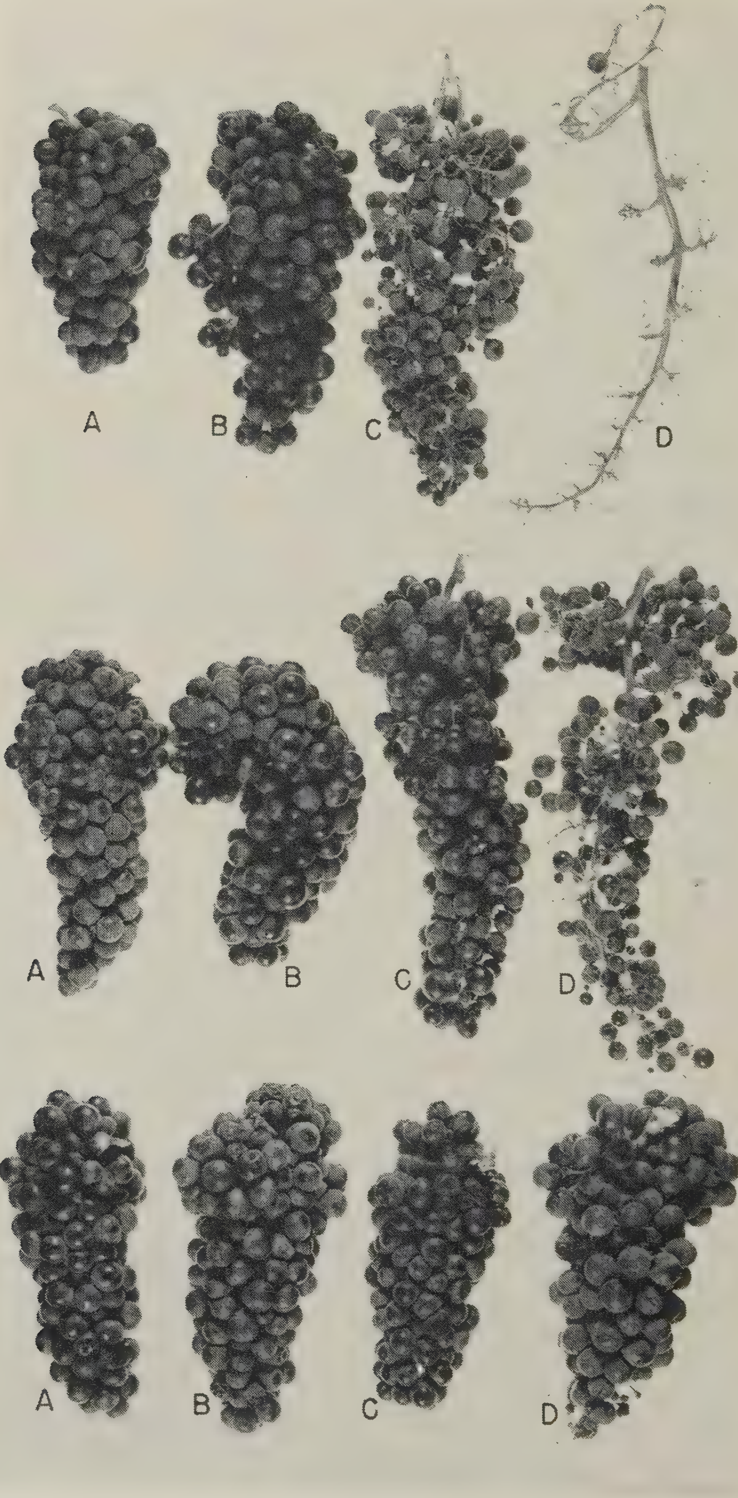


Fig. 17. Segments of Zinfandel shoots 169 days after being sprayed on April 7 with gibberellin at 1,000 ppm. Note that many cracks are canoe-shaped and that most are healed over. Photographed September 24, 1957.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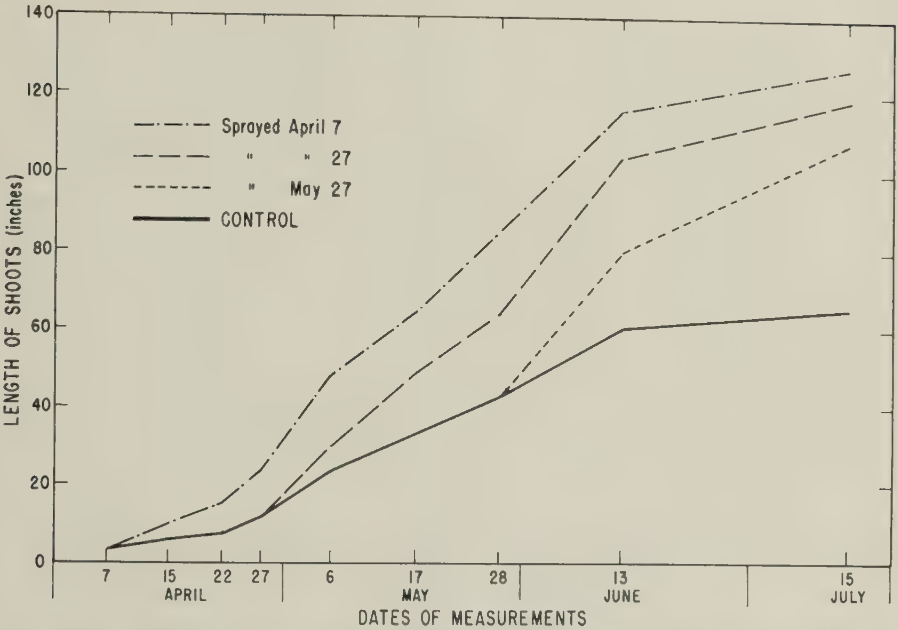

Fig. 19. Elongation of Zinfandel shoots sprayed with gibberellin at 100 ppm on April 7, April 27, or May 27. At each developmental stage there is a rapid acceleration of growth.

Fig. 18. (Page opposite.) Zinfandel grapes at harvest (September 23) from shoots sprayed on April 7 (upper), April 27 (middle), or May 27 (lower) with gibberellin at 0 (*A*), 10 (*B*), 100 (*C*), or 1,000 ppm (*D*). Note that clusters sprayed with 100 (*C*) or 1,000 ppm (*D*) at the first two sprayings are greatly elongated, and also that the compound is most toxic at the earliest stage of development. Photographed September 25, 1957.

Fig. 20. Zinfandel grapes 24 days after being sprayed on April 27 with gibberellin at 0 (*A*), 1 (*B*), 10 (*C*), 100 (*D*), or 1,000 ppm (*E*). Note that higher concentrations (*D, E*) elongate clusters and hasten flowering. Photographed May 21, 1957.

Fig. 21. Second crop clusters of Zinfandel grapes 107 days after being sprayed on June 4 with gibberellin at 25 ppm (lower). Unsprayed controls, upper. Note that second crop clusters (lower) are crinkled and twisted and have many shot berries and ovaries which failed to enlarge. Pedicels of treated clusters are longer than those of controls. Photographed September 19, 1957.

Fig. 22. Tokay shoots 17 days after being sprayed with gibberellin on April 27 at 1,000 ppm (right). Untreated control, left. Note that the treated shoot is longer and has larger clusters and leaves. Photographed May 14, 1957.

Fig. 23. Tokay grapes at harvest (September 27) from shoots sprayed on April 27 with gibberellin at 0 (*A*), 100 (*B*), or 1,000 ppm (*C*). Note that sprayed clusters (*B*) and (*C*) are greatly elongated and have many shot berries. Photographed September 30, 1957.

Fig. 24. Tokay grapes at harvest (September 30) after being dipped in gibberellin at 0 (*A*), 1 (*B*), 20 (*C*), or 500 ppm (*D*) at full bloom. Some shot berries resulted from the 1-ppm concentration (*B*), and many from 20 (*C*) and 500 (*D*). Note that berries are considerably elongated in the 500-ppm treatment. Photographed September 30, 1957.

Fig. 25. Tokay grapes 106 days after vines were sprayed on June 6 with gibberellin at 25 ppm (right). Control, left. Note shot berries in treated cluster (right). Photographed September 20, 1957.

Fig. 26. Clusters of Ribier grapes 115 days after being dipped at full bloom in gibberellin at 0 (*A*), 5 (*B*), 100 (*C*), or 500 ppm (*D*). Note the presence of some shot berries in the 5-ppm (*B*) and many in the 100-ppm (*C*) and 500-ppm (*D*) treatments. Many green shot berries occurred on the cluster dipped in the 500-ppm concentration (*D*), and the rachis is twisted and cracked. Photographed September 19, 1957.

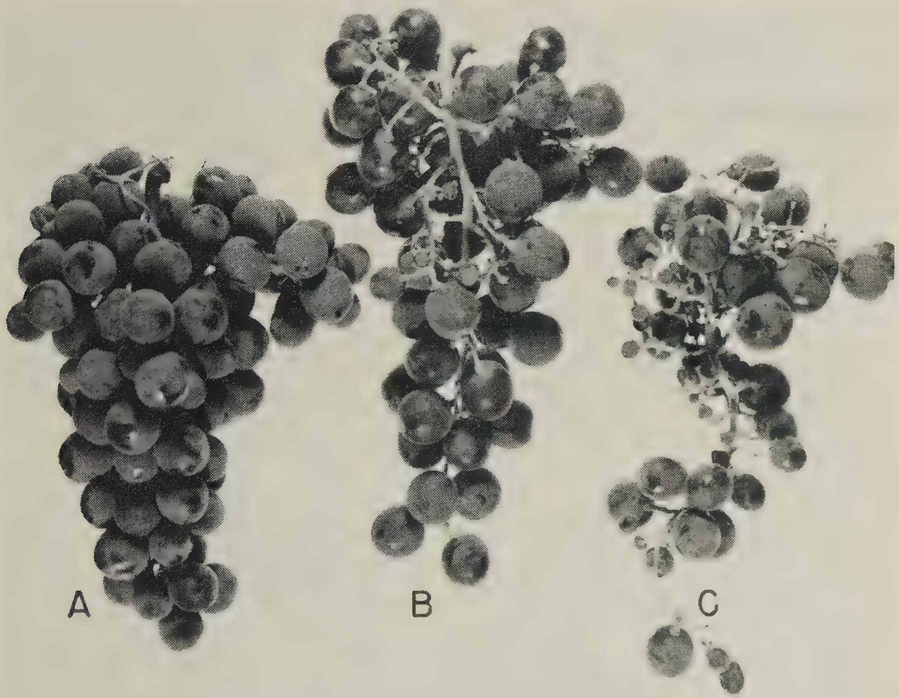

Fig. 27. Ribier grapes 129 days after spraying on May 27 (full bloom) with gibberellin at 0 (*A*), 5 (*B*), or 25 ppm (*C*). Note that sprays resulted in straggly berries with many shot berries. Photographed October 3, 1957.

Fig. 28. Red Malaga grapes after being sprayed on May 3 (upper) or June 4 (lower) with gibberellin at 0 (*A*), 5 (*B*), or 25 ppm (*C*). Some shot berries resulted from the spraying on May 3 (upper), and many from the treatment on June 4 (full bloom). Fruit from vines sprayed on June 14 or July 29 is omitted as it was similar to that of the controls. Photographed September 6, 1957.

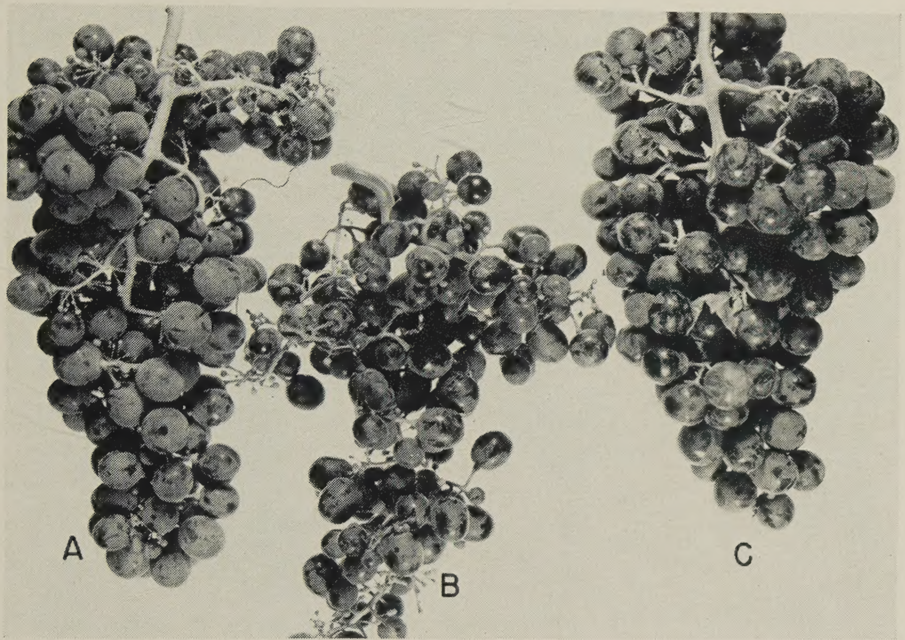

Fig. 29. Red Malaga grapes at harvest after being sprayed on May 3 (*A*), June 4 (*B*), or August 14 (*C*) with gibberellin at 25 ppm. The greatest number of shot berries resulted from the second treatment (*B*) and none from the August 14 treatment (*C*). Clusters from the treatment on June 14 are omitted, as fruit was similar to that of (*C*). Photographed September 6, 1957.

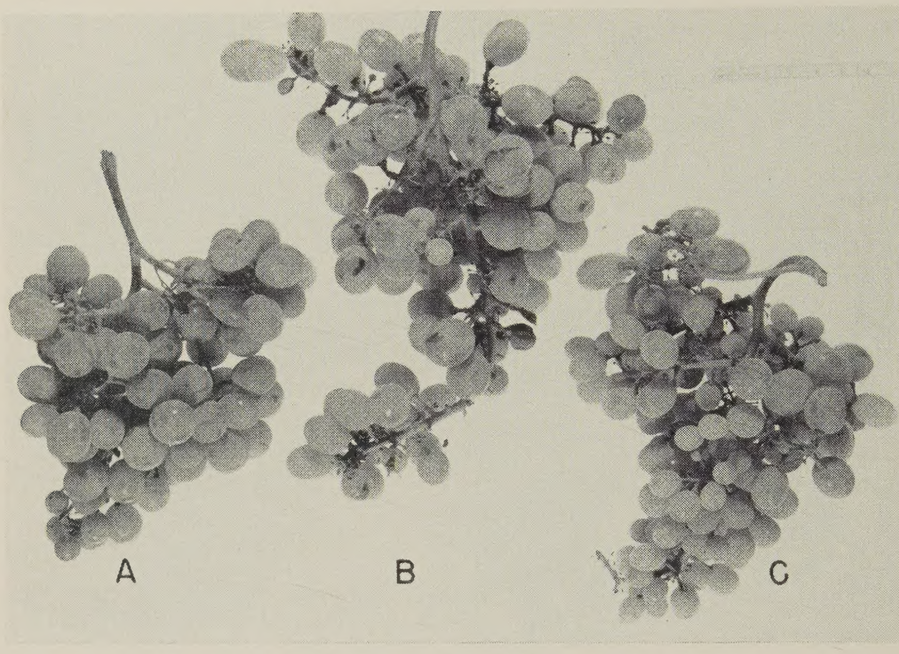

Fig. 30. Muscat of Alexandria grapes 113 days after being dipped in gibberellin at 0, 20, or 500 ppm. Note that the cluster treated at 20 ppm (*B*) is straggly, and that at 500 ppm (*C*) many berries failed to enlarge, although some others are slightly elongated. Photographed September 20, 1957.

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